Electrophysiological and Personality Factors Associated with Aberrant Visual Processing in Psychosis

A Dissertation
SUBMITTED TO THE FACULTY OF THE
UNIVERSITY OF MINNESOTA, TWIN CITIES
BY

Julia Martin Longenecker

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Robert F. Krueger, Scott R. Sponheim

August 2019

Acknowledgments

There are countless people who have contributed to me reaching this point in my education. Whether or not you are named here, I am grateful to each and everyone of you.

I would not have found my current path without the inspiration and guidance of my scientific mentors over the years: Deborah Burke, Robert Thornton, Brita Elvevåg, Dwight Dickinson, Jim Gold, Eric Chen, and Jill Goldstein. My doctoral advisor, Scott Sponheim, has my deepest appreciation for his encouragement and mentorship throughout my time at the University of Minnesota. I thank you for all you've done to challenge me, expand my scientific scholarship, and diminish the residual imposter syndrome. You have grounded my research and, perhaps without knowing it, made me believe that coveted work-life balance is possible. Thank you to my other advisors, both official and unofficial, who were involved in this dissertation and have cultivated my processional development throughout graduate school: Bob Krueger, Bonnie Klimes-Dougan, Colin DeYoung, Cheryl Olman, and Seung Suk Kang. Thank you to current and past members of the CAB Lab for the community and research support offered. As well, this dissertation would not be possible without the funding support of the Doctoral Dissertation Fellowship received through the University of Minnesota.

Thank you to all the friends who have stuck by me as I've flitted from city to city, especially Clio, Angela, Merav, Allie, Kelly, Martina, Jillian, Micaela, Matt, Kara, Zara, Brittany, Julie, Tori and Craig. Your laughter and support sustains me on a daily basis. A special shout out to Mindy, without whom I would not have survived at University of Minnesota; thank you for five years of constant encouragement, humor, and cat lady humor.

Thank you to my family for your unconditional love and support. Thank you to my parents for nurturing my curiosity, visiting me no matter how far I wander, and copyediting for over two decades.

Last but not least, thank you to Tim for being my husband, best friend, and off-the-record collaborator. You inspire and ground me on a daily basis. Thank you also for teaching me the importance of making the bed.

Dedication

To my parents,

who instilled in me the love of learning and sense of adventure that fueled this journey.

Abstract

Background: 'Apophenia', or the tendency to find patterns in unrelated perceptions, may link normative and pathological sensory experiences. Apophenia has been well-characterized by personality assessment, but has limited behavioral and functional correlates, particularly in clinical populations. Object detection is predicted by apophenia traits in normative populations. Behavioral and neurobiological object detection abnormalities are pervasive in schizophrenia, yet have not been investigated with respect to apophenia. The current set of studies explore multiple levels of perceptual disturbances in normative and psychiatric samples. **Methods:** Study 1 investigated personality and object detection in an undergraduate sample (N=191). The object detection task, Fragmented Ambiguous Object Task (FAOT), controls for low-level visual properties while presenting disjointed object representations of varying difficulty. Personality was comprehensively assessed with the Big Five Aspect Scale (BFAS), Multidimensional Personality Questionnaire (MPQ), and Personality Inventory for DSM-5 (PID-5). Study 2 sought to replicate Study 1 in a clinical population and extend the investigation to EEG in outpatients with psychotic disorders, first-degree biological relatives, and psychiatrically unaffected individuals. Event-related potentials (ERPs) – P1, N1, closure negativity (N_{CL}), and anterior components – were recorded with a 128 channel EEG system. Participants underwent comprehensive clinical assessment, and completed MPQ Absorption and PID-5. **Results:** In Study 1, object detection was positively associated with BFAS Openness, MPQ Absorption and PID-5 Psychoticism. Additionally, BFAS Conscientiousness and PID-5 Disinhibition predicted object detection. Study 2 did not replicate the association between FAOT and personality, or show an object detection deficit in psychotic disorders. The hypotheses regarding ERPs were largely unsupported. Instead, findings suggested group differences in semantic processing during FAOT, and an anterior component associated with frequent object detection. **Discussion:** Personality measures of apophenia were consistently related to experimentally manipulated visual perception in the general population but not persons with psychotic disorders. The present research attempted to unify observations in personality psychology, clinical research, and vision neuroscience of object detection. Deviations in perceptual functions that support the detection of ambiguous visual stimuli reflect normative expressions of trait-level apophenia. However, further investigation is necessary to connect apophenia to psychotic phenomenology in the context of mental illness.

Table of Contents

List of Tables vi

List of Figures vii

Chapter 1: Apophenia as a Link Between Behavioral and Neurobiological Foundations of Anomalous Perceptual Experiences 1

Personality & Apophenia 1

Object Detection as a Type of Visual Integration 5

Object Detection & Apophenia 9

Object Detection in Affective and Non-Affective Psychosis 11

Neural Processes Supporting Object Detection 17

Chapter 2: Apophenia Traits Predict Sensitivity to Ambiguous Objects 22

Study 1 22

Methods 25

Results 29

Discussion 36

Chapter 3: Associations Between Personality, Object Detection, and Event-Related Potentials in Psychotic Disorders 40

Study 2 40

Methods 48

Results 61

Discussion 73

Chapter 4: General Discussion 80

Conclusions 85

Bibliography 87

Appendix A. Waveforms and Topography of All ERPs.................................... 101

Appendix B. Image Detectability Effects on ERPs 105

Appendix C. Personality Scales.. 109

BFAS Openness and Intellect Items.. 109

MPQ Absorption Items 109

PID-5 Psychoticism Items.. 110

List of Tables

Table 1. *Sample Characteristics of Study 1 Undergraduate Participants* ………… 30

Table 2. *FAOT Performance as Predicted by BFAS Openness in Hierarchical Regression* …………………………………………………………… 31

Table 3. *FAOT Performance as Predicted by BFAS Domains in Hierarchical Regression* …………………………………………………………… 32

Table 4. *FAOT Performance as Predicted by PID-5 Psychoticism in Hierarchical Regression* ...…………………………………………...…… 33

Table 5. *FAOT Performance as Predicted by PID-5 Domain Traits in Hierarchical Regression* ……………………………………………..... 34

Table 6. *FAOT Performance as Predicted by MPQ Absorption in Hierarchical Regression* ………………………………………………………….... 35

Table 7. *Characteristics of Study 2 Clinical Sample* ………………………….……... 62

Table 8. *Group Membership as a Predictor of FAOT Performance in Multiple Regression Analysis* ……………………………….…..…… 63

Table 9. *MPQ Absorption as a Predictor of FAOT Performance in Multiple Regression Analysis* ……………………………………………………… 65

Table 10. *PID-5 Domain Traits as Predictors of FAOT Performance in Multiple Regression Analysis* ……………..………………………………. 67

Table B1. *Effects of Group and Condition on ERPs of Individualized Response Rates.* ……………..…………………………………………….. 108

List of Figures

Figure 1. *Visual Integration Paradigm Stimuli* ……………………………………… 6

Figure 2. *Fragmented Ambiguous Object Task Stimuli Development* ...…………….. 10

Figure 3. *Apophenia and Psychosis-Proneness Traits Predict Image Detection* 36

Figure 4. *Group Differences in the N400 Component* …………………………….… 71

Figure 5. *N^{F}_{CL} Component as Predicted by FAOT Behavioral Performance*………... 72

Figure A1. *Group Differences in the P1 Component* ……………………………….. 101

Figure A2. *Group Differences in the N1 Component* …………………….………. 102

Figure A3. *Group Differences in the Negative Closure (N_{CL}) Component* …..…….. 103

Figure A4. *Group Differences in the Anterior Components* …..……………..……… 104

Figure B1. *Waveforms for Frequently vs. Infrequently Detected Objects* ………….. 105

Figure B2. *Waveforms of Group and Individual Detection Rates* …………...……… 106

Chapter 1: Apophenia as a Link Between Behavioral and Neurobiological Foundations of Anomalous Perceptual Experiences

Historically, the term apophenia has described the pattern formation that leads to delusional beliefs in schizophrenia (Conrad, 1958). Today, apophenia is used more generally to refer to the tendency to find meaning in random or coincidental stimuli, often resulting from altered sensory experiences. Apophenia has been well-characterized by several self-report assessments of personality, but there is limited understanding of its behavioral and psychophysiological correlates. Given the perceptual modulations characteristic of apophenia, experimental paradigms focused on sensory processing may have a strong relationship to apophenia traits. Select studies have tied self-report apophenia measures in healthy populations to behavioral performance on object detection tasks, in which one connects elements of a visual field to form the shape of a known object. The connection between apophenia and object detection has not been investigated in clinical populations, in which both perceptual deficits and elevated apophenia are widely observed, nor has the relationship between apophenia and brain response during object detection paradigms. The current project aims to address these gaps in the literature by broadly characterizing apophenia across multiple levels of analysis – self-report questionnaires, a visual object recognition task, and electroencephalography (EEG) recordings – first in a community sample then in a clinical sample.

Personality & Apophenia

Pattern recognition in apophenia is largely described in terms of sensory interpretations, such as detecting an animal in clouds when others do not. One might be overcome by a perception, becoming enveloped by sounds or intensely experiencing a memory. There seems to be a combination of heightened sensory processing and ascribing meaning to the experience. The result could be functional (e.g., innovative) or maladaptive (e.g., departing from reality) pattern detection. Various personality measures capture a range of apophenic experiences and have been shown to load on the same normative personality trait: Openness to Experience/Intellect.

Personality traits broadly describe the way an individual is inclined to think, behave, and feel. Openness to Experience/Intellect, Neuroticism, Extraversion, Agreeableness, and Conscientiousness are the traits in the Five Factor Model (FFM), an empirically-derived, dimensional framework for normative personality (Costa & McCrae, 1992; John, Naumann, & Soto, 2008). At a lower level of the hierarchical structure of personality, each of the five factors splits into two subordinate aspects, as captured by the Big Five Aspect Scale (BFAS; DeYoung et al., 2007). The Openness to Experience/Intellect trait is composed of the aspects Openness, characterized by appreciation for aesthetics and the arts, and Intellect, a seeking of intellectual stimulation and abstraction. The differentiation between these two aspects may be relevant to maladaptive expressions of personality, such as those observed in clinical populations.

Openness relates to a variety of scales in the normative and maladaptive range that reflect a tendency to experience unusual associations and potent percepts, characteristic of apophenia. Someone high in BFAS Openness might strongly agree that they "See beauty in things that others might not notice." Likewise, on the Multidimensional Personality Questionnaire (MPQ) subscale Absorption they might endorse, “I can sometimes recall certain past experiences so clearly and vividly that it is like living them again” (Tellegen & Atkinson, 1974a). Prior research indicates that traits of apophenia, such as MPQ Absorption, occur along a continuum within clinical and non-clinical populations (Coleman, Levy, Lenzenweger, & Holzman, 1996; Tsakanikos & Reed, 2005; Yaralian, 2000). Elevated apophenia is common in the general population, but especially in first-degree relatives of people with psychotic disorders and individuals with psychotic psychopathology, including schizophrenia spectrum and bipolar affective disorders (Camisa et al., 2005; DeYoung, Grazioplene, & Peterson, 2012; Fyfe, Williams, Mason, & Pickup, 2008; Tellegen et al., 1988; Wilson & Sponheim, 2014). This supports the idea that Openness may be on a continuum with more maladaptive manifestations of personality associated with psychosis.

Positive schizotypy is a more extreme facet of the Openness domain. Positive schizotypy describes anomalous perceptual experiences and beliefs, and magical thinking. Negative schizotypy, such as interpersonal problems, and disorganized schizotypy, such as odd behaviors and speech, do not fall within the Openness domain. Like other measures of apophenia, positive relates to how one processes sensory input and interprets meaningful patterns. The Schizotypal Personality Questionnaire (SPQ) contains items such as “Have you often mistaken objects or shadows for people, or noises for voices?” (Raine, 1991). Responses on maladaptive measures of personality like SPQ indicate traits that are relatively stable over the lifetime; high apophenia may be conceptually linked to psychosis, but it does not necessarily parallel acute changes in symptoms of psychosis. Schizotypy appears continuous across normative and clinical populations (Asai, Sugimori, Bando, & Tanno, 2011). It shows a normal distribution within the general population, and marked elevations in families of persons with psychosis, and individuals with psychotic diagnoses (Calkins, Curtis, Grove, & Iacono, 2004; Docherty & Sponheim, 2008; Raine et al., 1994; Rossi & Daneluzzo, 2002; Silberschmidt & Sponheim, 2008; Tackett, Silberschmidt, Krueger, & Sponheim, 2009). Individual differences in apophenia on normative and maladaptive instruments appear to capture aspects of psychopathology that cross conventional diagnostic classifications.

The measures of apophenia mentioned above also collectively load on the Openness/Intellect factor. More specifically, at the aspect level Absorption and positive schizotypy cluster with Openness, while intelligence and creativity indices cluster more closely to Intellect (DeYoung et al., 2012). Absorption, positive schizotypy, creativity, and intelligence form a simplex whereby facets on the far poles – intelligence and measures of apophenia – are weakly *negatively* correlated. Thus, while Openness and Intellect load on the same personality factor, the specific facets that contribute to heightened apophenia form a margin of Openness that underscores perceptual disturbances and may relate to clinical phenomenology.

The relationship between apophenia and intelligence suggests that cognitive factors moderate one's ability to employ apophenia effectively in the real-world. Intellectual deficits may trigger an inability to separate functional connections from maladaptive ones, leading to suspiciousness, paranoia, and delusional thinking associated with psychosis — symptoms that can make it difficult to establish and maintain social relationships, advance professionally, or perform the daily tasks necessary for independent living. In contrast, individuals high on apophenia who have intact intellectual functioning may exhibit above average functional outcomes, given that the combination of high apophenia and high intelligence likely facilitates the generation and application of creative thinking.

Posing these hypotheses in a research context is difficult due to the fleeting nature of sensory experiences and perceptual aberrations underlying psychotic symptoms. A similar problem arises in creativity research, which has been addressed through development of both self-report measures of creative achievements and divergent thinking tasks in which the novelty and appropriateness of participant responses is quantified. Paradigms containing fragmented images, such as those in visual integration tasks, present a possible opportunity to identify experimental tasks that capture apophenia. In Study 1, a visual integration paradigm allows us to explore the relationship between self-report and task-based measures of perceptual processing in a controlled, laboratory environment.

Object Detection as a Type of Visual Integration

Visual integration is an area of visual processing in which the viewer must combine two or more items to detect a meaningful representation within the field of vision. Paradigms include object recognition, perceptual closure, visual illusions, perceptual motion, and global-local judgments. Despite their similarities, these tasks include diverse stimuli and subtle differences in instruction. As a result, they often require substantially different cognitive processes. Perceptual motion tasks, for example, require participants to interpret how two moving objects interact and accuracy on these tasks have been linked to individual differences in theory of mind abilities (Fyfe et al., 2008). In contrast, object recognition and perceptual closure tasks both require participants to discern a real-life object from a degraded representation, such as disjointed

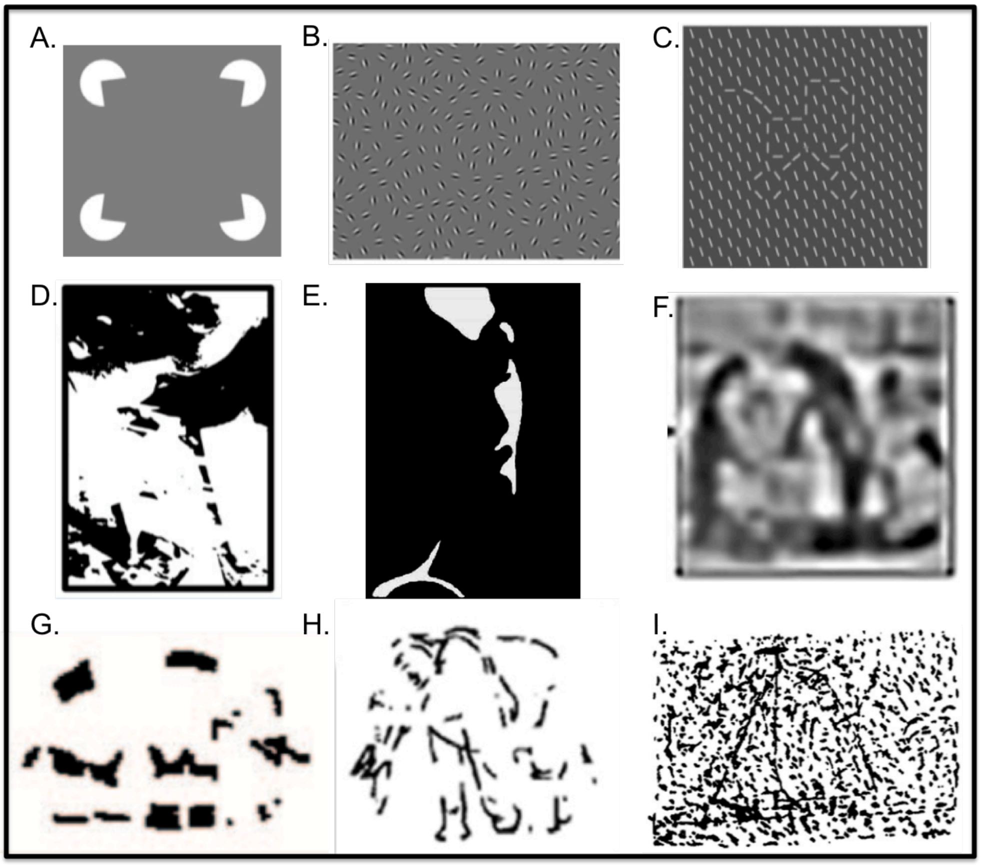

Figure 1. Visual Integration Paradigm Stimuli. *A) Kanizsa contours give the illusion of a square between the "pac-men"; B) JOVI images contain a tilted oval, here pointing toward the left, amongst background noise; C) a fragmented outline of a baby carriage amongst background noise in the Cardin et al. (2001) task; D) a degraded black and white scene of a child with some outlines removed (Teufel et al., 2015); E) Mooney face illusion tasks use black and white depictions of faces in which some lines have been removed to create more ambiguous images (Mooney & M., 1957); F) two figures in a blurred scene in the Perception of Meaning task (Partos et al., 2016); G) Gestalt closure tasks remove portions of solid object drawings like this elephant; H. Snodgrass & Corwin line drawings become progressively less degraded until participants recognize the object (level 3 elephant shown); I) this Snowy Pictures stimulus is a sailboat line drawing embedded in background noise (Moritz et al., 2014).*

lines set among irrelevant lines; performance on these types of tasks necessitates cognitive coordination of incoming sensory information with contextual knowledge.

Object detection tasks require participants to discern whether there is a real-life object present in a degraded visual representation. Participants must associate a collection of fragmented segments to detect a meaningful representation within the field of vision. Target objects range from geometric shapes to more semantically varied stimuli, such as animals (see Figure 1). Stimuli are classically gray scale though they range in other properties such as contrast and density. While all reduce distinguishability by blurring or fragmenting the target object, some also introduce background noise (i.e., panels B, C, D, F, I in Figure 1). Performance on these types of tasks requires matching sensory input to existing semantic knowledge of objects in the world. Participants must take in basic visual features and match the sensory input to an existing concept. It is an ideal approach by which to explore how low level visual processes interface with higher-order mechanisms.

Four variations in object detection experimental design are notable for how they might influence task demands. First, a variety of target objects are used. The semantic qualities of fragmented representations may modulate recognition difficulty. An assortment of animate and abstract objects is more difficult to discern than geometric shapes and likely relies on a more extensive neural network (Keane, Joseph, & Silverstein, 2014; O'Shea & Walsh, 2006; Partos, Cropper, & Rawlings, 2016). The type and range of object classes influences behavioral and neural engagement. Second, the physical qualities of the stimuli differ. Physical properties such as the contrast between background and target colors, clarity of segment edges, width of stimuli within the scope of vision, and brightness of the background affect image processing along visual pathways (Bullier, 2001). Third, background elements differ, with some tasks having a stable, solid colored background while others have random segments surrounding the target at different angles. This influences contextual differentiation of target versus background (Albright & Stoner, 2002). Fourth, participant instructions range. Tasks that verify responses as being correct through instructing participants to identify stimuli ensure that all participants are engaged and accurately interpreting stimuli. However, they also rely on explicit, lexical naming abilities that may be impaired or slowed in clinical populations (Lau et al., 2015). Verbal abilities represent one of the largest neuropsychological deficits in schizophrenia, particularly with respect to lexical access (Covington et al., 2005). Objective judgments of stimulus characteristics is an alternative approach that engages participants with the stimuli without relying on lexical-phonological mapping. Jittered-Orientation Visual Integration (JOVI; Figure 1B), developed by CNTRACs (Silverstein et al., 2012), uses left/right judgments on the directional tilt of ovals; Kanizsa illusion instructions (Figure 1A) often take a similar approach to accuracy by asking whether a square is fat or skinny. Paradigms with varied shapes (e.g., animals) usually ask participants to simply respond “yes” when they see a known object in the stimulus and “no” when they do not. Given the multitude of behavioral paradigms employed in the visual integration literature, and the range of cognitive capacities necessary to support performance on each, contradictory findings in the literature can be difficult to interpret.

Object Detection & Apophenia

Object detection is a class of visual experiments that shows promise in connecting apophenia traits to objective performance metrics on a sensory task. Findings in community samples offer evidence that object detection is affected by common processes related to apophenia across the general population. Persons with high apophenia, on scales of positive schizotypy and an analogue to Absorption, are superior to healthy controls when identifying scrambled images (Partos et al., 2016; Uhlhaas, Phillips, & Silverstein, 2005; Wallace, 1990). The studies highlight a symbiotic relationship that has not been explored in clinical populations and demonstrate an unambiguous relationship between apophenia and visual perceptual abnormalities that is sustained in larger sample sizes.

Likewise, better object detection has also been observed in persons at "ultra-high-risk" for psychosis (Teufel et al., 2015). Ultra-high-risk status refers to individuals who are expected to later develop a psychotic mental illness based on structured clinical assessments; they express psychiatric symptoms below the threshold for diagnosis and about one half later develop a psychotic diagnosis (Fusar-Poli et al., 2012). It would be useful to extend these investigations to family members of persons with psychotic diagnoses. The few visual integration studies that have included first-degree relatives in their sample reveal conflicting findings of genetic liability (Schallmo, Sponheim, & Olman, 2013; Yeap et al., 2006). To my knowledge, apophenia and object detection have not been studied in a population with shared genetic liability for psychosis. In addition to high schizotypy, unaffected first-degree relatives show heightened subclinical psychotic experiences and certain cognitive deficits, with effect sizes falling between those of healthy controls and persons with schizophrenia (Snitz, MacDonald, & Carter, 2005; Varghese, Saha, Scott, Chan, & McGrath, 2011). Including relatives in research of object detection may better capture the full distribution of apophenia and distinguish between

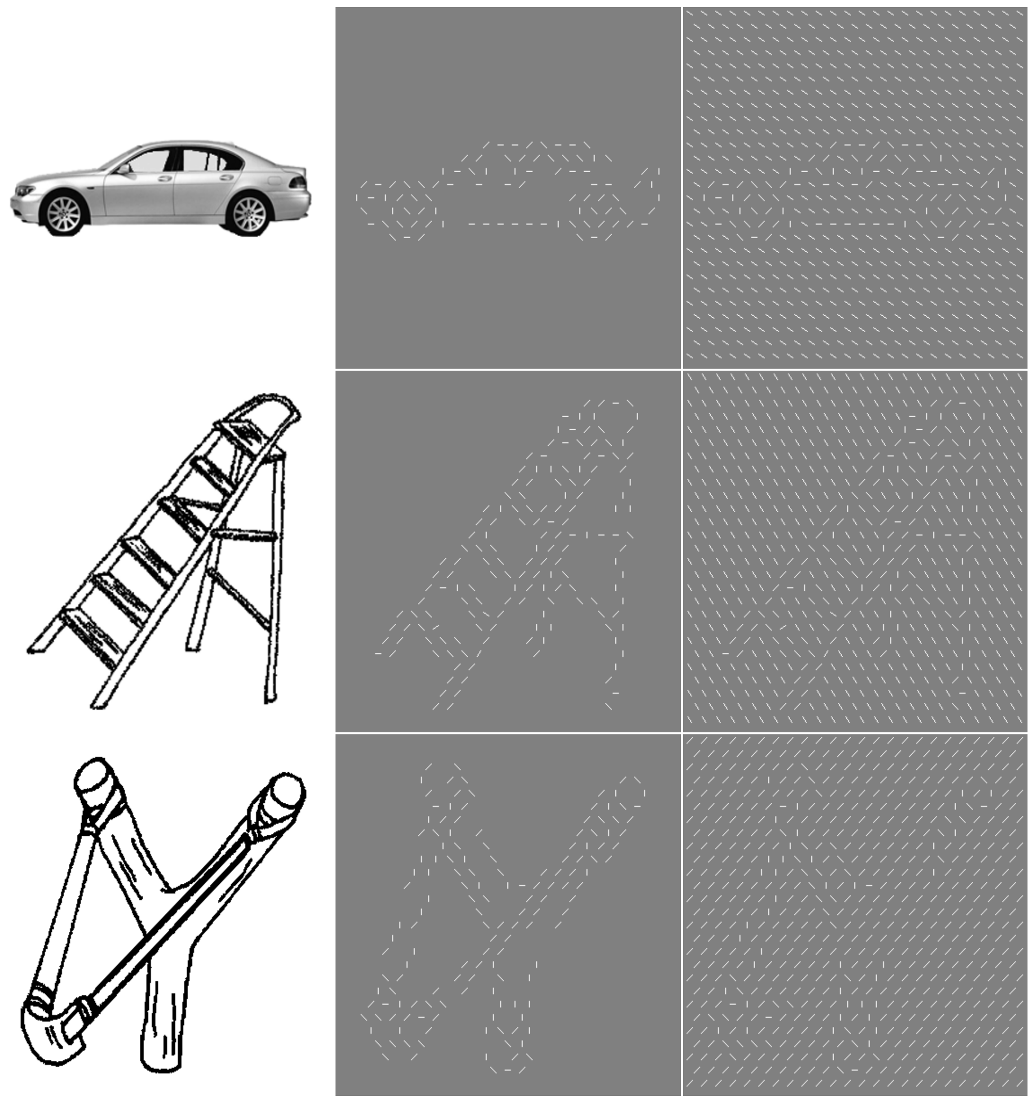

***Figure 2. Fragmented Ambiguous Object Task Stimuli Development**. FAOT stimuli were created from real pictures (left). A "winner-takes-all" algorithm generated fragmented line drawings of each picture (middle). A background of identically sized fragmented lines was added to form the final stimuli (right). Image borrowed with permission from Olman, et al. (submitted).*

effects of maladaptive personality traits and psychiatric variables such as psychoactive medication and clinical state.

Studies in normative and at-risk samples also suggest that the paradoxical relationship between Openness and Intellect facets moderates object detection performance. Accuracy was heightened for those with high positive schizotypy (i.e., high apophenia), and decreased when high levels of thought disorder or disorganized thinking were simultaneously endorsed (Partos et al., 2016; Teufel et al., 2015; Uhlhaas, Silverstein, Phillips, & Lovell, 2004). Sensitivity to perceptual input could be boosted by apophenia while response coherence is reduced by low intelligence. Thus, in isolation high apophenia would create higher rates of hits on object detection tasks, as has been reported in psychosis-prone populations. However, cognitive disruption would introduce faulty application of prior knowledge, resulting in difficulty discerning meaning from noise. Performance ranges from deeply disrupted in chronic schizophrenia, to slightly below healthy controls in first-episode schizophrenia, to superior than controls in non-clinical schizotypy groups. This seemingly contradictory pattern introduces the strongest evidence that apophenia and intelligence exert an opposing relationship on object detection abilities. The behavioral results suggest a graded relationship across a continuum of psychosis expression that is best explained by an interaction between Openness and Intellect aspects across clinical, at-risk, and normative populations.

Object Detection in Affective and Non-Affective Psychosis

Object detection is disrupted in schizophrenia as compared to psychiatrically healthy controls, and may be broadly associated with psychosis rather than with a specific diagnostic category. Two previous reviews broadly summarize the visual integration schizophrenia literature published from 1974 to 2017 (Silverstein & Keane, 2011; Uhlhaas & Silverstein, 2005). In both reviews, behavioral performance by persons with schizophrenia is shown to be unconventional across a wide range of tasks including poor integration of elements into the larger context of a scene, motion detection of multiple targets, decreased bias to certain visual illusions[1], and impairment detecting fragmented outlines. Though there is a dearth of relevant studies on bipolar disorder, a recent study demonstrates that contour integration deficits occur across the affective and non-affective psychotic spectrum (Grove et al., 2018). Tasks that involve broken figures (i.e., a shape or object as opposed to a single Gabor patch) show some of the largest performance gaps between control and schizophrenia groups (King, Hodgekins, Chouinard, Chouinard, & Sperandio, 2017; Uhlhaas & Silverstein, 2005).

That visual integration is intact under certain conditions and does not represent a generalized deficit makes it a particularly appealing research target within severe mental illness. Recently, the National Institute of Mental Health (NIMH) and other leading research entities have acknowledged the translational value of research exploring visual impairment in schizophrenia and its neurobiological underpinnings. Likewise, the

[1] Visual illusory tasks have received substantial attention since persons with schizophrenia often perceive the stimuli *more accurately* than controls; that is, participants with schizophrenia are less susceptible to distorted perception of visual stimuli within these controlled experiments (Keane, Silverstein, Wang, & Papathomas, 2013; Schneider et al., 2002). Thus, visual illusions have been used as evidence that visual integration does not represent a general deficit in schizophrenia. It is important to frame these reduced illusory susceptibilities within a functionally adaptive context. In fact, the illusory task metrics reward poor visual integration; participants have improved accuracy when they perceive the individual elements in the visual field rather than incorporating the overall context (for example, a circle surrounded by larger circles is judged as smaller than an identically sized circle with no surround; Yang et al., 2013). Outside the laboratory, a deficit in judging relative size may impair depth perception or other assessments of the environment. This shift in thinking does not reduce visual integration to a generalized deficit. Reduced illusory susceptibility occurs as a result of contrast but not luminance modulation, suggesting that luminance processing is intact in schizophrenia while contrast processing is abnormal (King et al., 2017).

Cognitive Neuroscience Test Reliability and Clinical applications for Schizophrenia (CNTRACs) Consortium considers visual integration one of four cognitive domains that can optimally assess treatment response in schizophrenia (Gold et al., 2012). The visual perception subconstruct of the NIMH Research Domain Criteria (RDoC) matrix specifically cites object recognition, contour integration and visual illusion experimental paradigms, and self-reported perceptual anomalies as units of analysis. The RDoC framework recognizes that psychological phenomena may be better understood and more closely linked to biological substrates using a dimensional framework (Yee, Javitt, & Miller, 2015). The field can leverage two angles of the dimensional framework to better understand visual integration. First, we can consider visual integration across a spectrum of psychiatric disorders with shared diagnostic criterion (e.g., schizophrenia spectrum disorders and bipolar affective disorders) and in populations with subthreshold expressions of psychosis. Second, we can use dimensional scales, such as self-report measures of perceptual anomalies or symptom scales, to distinguish state and trait variables that are consistently related to visual integration.

Many of the apophenia measures mentioned previously measure self-report of perceptual anomalies, yet they have been minimally leveraged in research of clinical populations. Between-groups comparisons of participants with schizophrenia versus psychiatrically unaffected controls on visual integration performance have been widely reported across multiple paradigms. Considerable heterogeneity has been found in between-group studies of visual integration in schizophrenia as compared to correlational findings using measures of schizotypy (Panton, Badcock, & Badcock, 2016). This suggests that diagnosis is not the unit of analysis most closely associated with visual integration, and that dimensional approaches may benefit clinical research of vision.

Nonetheless, empirical studies have not robustly demonstrated associations with clinical symptomatology. The most consistent patterns to emerge have been a relationship with disorganized symptoms, followed by positive symptoms[2]. In persons with bipolar disorder, mania may also be associated with abnormal performance and neural activity (Shaffer et al., 2017; Eunice Yang et al., 2013). Disorganized symptoms are correlated with poorer accuracy on illusory contours (i.e., Kanizsa) and contour integration (i.e., JOVI) tasks (Butler et al., 2013; Feigenson, Keane, Roché, & Silverstein, 2014; Joseph, Bae, & Silverstein, 2013; Keane et al., 2014; Silverstein & Keane, 2011; Uhlhaas & Silverstein, 2005). The relationship with positive symptoms has been more equivocal. Positive symptoms have been associated with higher false alarm rates and, when controlling for disorganization, superior performance (Feigenson et al., 2014; Uhlhaas et al., 2006). The relationship between visual integration and symptoms parallels the relationship between visual integration and disorganized versus cognitive perceptual schizotypy factors in non-clinical samples. In fact, one clinical study has found that positive symptoms were associated with superior performance, while cognitive disorganization exerted an opposing effect, particularly in first-episode patients (Feigenson et al., 2014). Silverstein & Thompson (2015) theorized specific relationships

[2] Classically, all schizophrenia symptoms were subsumed under two labels: positive and negative (Andreasen, 1990; Crow, 1980). Empirical work has repeatedly shown across various instruments that symptoms are better accounted for by multiple factors (Dingemans, Linszen, Lenior, & Smeets, 1995; Kopelowicz, Ventura, Liberman, & Mintz, 2008; Liddle, 1987; Lindenmayer, Bernstein-Hyman, & Grochowski, 1994; Mueser, Curran, & McHugo, 1997). Positive (hallucinations and delusions), negative (reduced affect, amotivation, anhedonia), and disorganized (odd speech and behavior) symptoms are the most reliably produced factors and the delineations that the current manuscript relies upon. Depression/anxiety, excitement, and mania have also derived from some analyses.

between clinical factors and levels of processing: disorganized symptoms are linked to arranging visual information, while positive symptoms such as hallucinations and delusions decrease the ability to resolve visual features using prior knowledge.

If current symptoms are strongly associated with visual integration abilities, we would expect that task performance would change with clinical state. Within patients, some studies note that visual integration performance improves concurrent with symptom improvements, whereas others found that performance was dependent on illness chronicity but not current symptoms (Butler et al., 2013; Feigenson et al., 2014). The two known longitudinal studies had small samples (<20) and conflicting results. In one, amelioration of disorganized symptoms correlated with poorer contour integration performance, while the other found no relationship between performance and symptoms (Feigenson et al., 2014; Uhlhaas et al., 2005). This raises the possibility that traits, which are more stable over time than clinical symptomatology, have a stronger relationship with visual integration performance. Given the heterogeneity of symptom expression across schizophrenia spectrum diagnoses, small sample sizes and between-group designs may obscure the relevance to the broad spectrum of thinking and behavior that are included in diagnostic criteria. Utilizing larger samples and trait measures of apophenia may identify stable factors that are more homogenously related to both clinical phenomenology and perceptual disorganization deficits.

Object recognition paradigms that present representations of a variety of meaningful images are the most difficult for persons with psychosis to detect and identify. Objects in the Snodgrass & Corwin paradigm (Figure 1, panels G and H) have high semantic value, such as context and memories associated with similar objects. These objects are more difficult for patients to integrate than inanimate geometric shapes (Partos et al., 2016). Significant deficits were reported across all clinical studies of Snodgrass & Corwin stimuli reviewed (Amiaz et al., 2016; Azadmehr et al., 2013; Doniger, Foxe, Murray, Higgins, & Javitt, 2002; Doniger, Silipo, Rabinowicz, Snodgrass, & Javitt, 2001; Sehatpour et al., 2010). Tasks that contain known objects other than geometric shapes require an extensive search through known object representations. The result is thought to be greater demand on higher-order cognitive processes to match the sensory experience with familiar images and prior knowledge (Kveraga, Ghuman, & Bar, 2007; Urooj et al., 2014). In support, one study found that the later stage of processing that conceptually integrates global shape is disrupted in schizophrenia while the initial filling in — the initial detection — of an illusory contour is intact (Keane et al., 2014). The properties of Snodgrass & Corwin paradigms make it difficult to deduce which levels of processing are disrupted. First, the stimuli are not matched on basic visual properties. Second, many of the tasks based accuracy on participants' ability to identify (i.e., name) each object. As discussed earlier, this relies on an additional linguistic processes that are not required for delineation of an object form and may be disproportionately impaired in schizophrenia.

The JOVI contour integration task, developed by CNTRACs, addresses many of the limitations of Snodgrass & Corwin stimuli (Silverstein et al., 2012). JOVI presents fragmented oval outlines that participants must detect within a background of fragmented elements. Low-level visual properties such as contrast, orientation, and luminance are reliably controlled across stimuli. Contour detection deficits are usually demonstrated in schizophrenia spectrum disorders (Grove et al., 2018; Silverstein, 2016; Silverstein & Keane, 2011). However, the deficits are not as pervasive as with Snodgrass & Corwin paradigms. Persons with schizophrenia have less trouble detecting JOVI ovals in earlier stages of illness, which has been leveraged as evidence that deficits are associated with the disease itself (Feigenson et al., 2014; Keane, Paterno, Kastner, & Silverstein, 2016). The one study to consider contour integration in a spectrum of severe mental illness found that deficits were present across schizophrenia, schizoaffective disorder, and bipolar disorder when there was a lifetime history of psychotic symptoms (Grove et al., 2018). Taken in combination with the anomalous visual integration seen in at-risk populations, it seems more likely that the deficits occur along a spectrum that is not disease-specific but rather associated with psychotic phenomenology. In addition, high-level processing is less implicated in JOVI since the stimuli are consistent geometric shapes that may demand less matching between sensory input and prior knowledge. The limited evidence on visual integration in bipolar disorder suggests higher-order cognitive processes are selectively affected, though these conclusions are not specific to contour integration paradigms (Jahshan et al., 2014; Kéri, Kelemen, Benedek, & Janka, 2005). A paradigm that requires participants to integrate multiple elements into a known shape while carefully controlling for basic visual properties would complement JOVI literature, and serve as a basis for comparison of neurobiological basis in neuroimaging and electrophysiological studies.

Neural Processes Supporting Object Detection

Successful object detection is supported by a diverse set of cognitive processes that integrate visual elements into a cohesive, meaningful form. Many of these processes are automatic and unconscious, so that a person may perceive object borders or feel an object looks like *something* familiar before attaching a name or functional qualities to a form (Hurme, Koivisto, Revonsuo, & Railo, 2017; Lau et al., 2015). The overarching understanding is that iterative neural processes group sensory input and appropriately match it to stored representations. However, the specific timing and neuroanatomical sources of these coordinated processes are not well established.

Perceiving an object relies on a widespread brain network that stretches from the retina where input is projected to the lateral geniculate nucleus (LGN), and primary visual, temporal, parietal, and frontal cortices (DiCarlo, Zoccolan, & Rust, 2012; Farivar, 2009; Kveraga et al., 2011; Urooj et al., 2014). Classically, a dorsal and a ventral visual stream were thought to be anatomically and functionally segregated during perceptual processing (Freud, Plaut, & Behrmann, 2016; Kravitz, Saleem, Baker, Ungerleider, & Mishkin, 2013; Ungerleider & Haxby, 1994). The dorsal stream, referred to as the 'where' or 'how' pathway, specializes in quickly transferring visuospatial information and motion from V1 into the parietal cortex (for a discussion of how the dorsal pathway may also support aspects of object recognition such as orientation and depth, see Farivar, 2009; and Freud, Plaut, & Behrmann, 2016). The ventral stream, or 'what' pathway, governs detail oriented information that supports perception like object and face recognition (Goodale & Milner, 1992; Kravitz et al., 2013; Ungerleider & Haxby, 1994). The ventral stream anatomically diverges from the dorsal stream in mid-level visual regions and culminates in the lateral occipital complex (LOC), an area that includes lateral occipital cortex and posterior fusiform gyrus. Contemporary research illustrates a highly connected and multidirectional network of neural communication that may unite the two visual streams more than previously believed (Bar et al., 2006; de Haan & Cowey, 2011; DiCarlo et al., 2012). When sensory perceptions flow ‘bottom up’ from lower-order brain structures such as the primary visual cortex to higher-order regions, the activity is described as feedforward. Feedback occurs from higher to lower-order levels of the visual hierarchy at short distances within local circuits and at long-range between regions. As well, lateral communication occurs within areas and between visual pathways. Effective neural coordination via these various communication modes allows one to perceive the physical qualities of a stimulus, integrate and segregate the scene properly, and attach meaning to the perception.

Three main theories explain how neural activity leads to conscious perceptual experiences: 1) interactive or parallel hierarchy, in which feedforward processing and long-range feedback between areas are ongoing (Bar et al., 2006; Jardri & Denève, 2013); 2) serial hierarchy in which neural communication is primarily feedforward, cascading from low to high level regions of the visual hierarchy (DiCarlo et al., 2012); and 3) patchwork model of connectivity through a distributed network that departs from the dual visual stream pathways (de Haan & Cowey, 2011). The current study focuses on the iterative hierarchy because of the substantial empirical evidence supporting the framework. A serial hierarchy model is unlikely given evidence that object recognition is enhanced by cuing and can occur through top-down feedback when basic visual regions have lesions (Bastos et al., 2015). The patchwork model remains in the early stages of implementation; as well, the patchwork and iterative hierarchy models are not necessarily mutually exclusive.

Within an iterative hierarchy, it is unclear whether feedforward or feedback might contribute to object detection difficulties in psychotic disorders like schizophrenia or bipolar disorder. Patients with schizophrenia demonstrate disrupted neural activity at various stages of fragmented object detection. Within prediction error theories, higher level regions, such as the temporal and orbitofrontal cortices, curate prior knowledge and deliver guesses through feedback (Kveraga et al., 2007; Urooj et al., 2014). The LOC, implicated in the final stages of the ventral perception steam, has been conceptualized as the region where sensory messages are matched to preexisting knowledge in the last stages of object recognition, perhaps representing a hub where feedforward and feedback activity meets (Shpaner, Molholm, Forde, & Foxe, 2013). Prior knowledge delivered via feedback could bias visual object identification if guesses are weighted more heavily than sensory input in the neural network (Bar et al., 2006; Foxe, Murray, & Javitt, 2005). In the primate brain, feedback connections appear to be more numerous and cross more hierarchical levels than feedforward connections, suggesting that feedback processes are abundant and important aspect of accurate perception (Markov et al., 2014). Persons with schizophrenia are thought to retrieve less appropriate guesses from semantic knowledge, applying an incongruous meaning to visual perceptions (Bar et al., 2006; Kveraga et al., 2007; Volberg, Wutz, & Greenlee, 2013). MRI and EEG research reliably show reduced LOC activation in schizophrenia, the region in which prediction errors are thought to be detected (Azadmehr et al., 2013; Butler et al., 2013; Doniger et al., 2000; Rivolta et al., 2014; Sehatpour et al., 2010b; Silverstein & Keane, 2011; but not Silverstein et al., 2009). As well, connectivity between prefrontal and visual areas is disrupted in schizophrenia (Calderone et al., 2013; Silverstein et al., 2009). The abnormalities described in schizophrenia do not exclusively implicate feedback activity since have been found at a potential meeting point of feedback and feedforward communication. Errors could originate from feedforward input from early visual regions.

Within another iterative hierarchical theory, the circular inference model, top-down and bottom-up information is conveyed by excitatory neural responses and controlled by inhibitory loops that prevent redundant messages and preserve the source of the information (Jardri & Denève, 2013). In the presence of undermined feedforward inhibition loops, the neural network becomes imbalanced and preferentially weights incoming perceptual experiences over internal knowledge and predictions. Computational neural networks produce visual errors when 'bottom-up' signals are not controlled by inhibitory loops, resulting in more vivid percepts, and mistaking external messages as internally generated (Denève & Jardri, 2016). Thus, decreased feedforward inhibition of visual information in the brain could explain the visual deficits observed in schizophrenia. Indeed, the primary visual cortex remains highly activated when patients with schizophrenia view fragmented images despite a reduction in controls, and predicts poor performance (Silverstein et al., 2009; Silverstein et al., 2015; Silverstein & Phillips, 2003; Yoon et al., 2009). Thus far, circular inference has been based on computational algorithm results; linking neural and physiological patterns to circular inference will further develop the mechanisms of the theory and allow it to be empirically tested.

Manipulating the balance between low-level visual characteristics and higher-order processing may add understanding to the interaction between feedforward and feedback processes. For example, we would expect stimuli with greater semantic elaboration to disproportionately rely on feedback from higher-order regions of the brain. Timing is an important element of visual processing. If processing moves from lower levels of the primary visual cortex through dorsal and ventral hierarchies, the timing of electrophysiological recordings should reflect that serial cascade. On the other hand, early activation of higher-order regions would be consistent with ongoing high-level feedback in the iterative hierarchy model. One caveat is that the same brain region may serve different roles or communicate with different areas at different stages of processing (Hurme et al., 2017). Thus, understanding *when* integration becomes abnormal within visual processing networks of patients with schizophrenia may help us differentiate obstacles to object detection. Study 2 investigates the timing of potential feed-forward and feedback disruption using event-related potentials (ERPs). Furthermore, it explores the theory that personality traits may be differentially linked to neural communication.

Chapter 2: Apophenia Traits Predict Sensitivity to Ambiguous Objects

Study 1

Apophenia questionnaires primarily query about perceptual experiences, including visual misperceptions. However, few studies have made direct connections between apophenia traits and visual abilities in experimental tasks. One study has examined the relationship between Openness and binocular rivalry, a paradigm in which each eye views a different picture (Antinori, Carter, & Smillie, 2017). Antinori and colleagues (2007) have found that healthy participants high in Openness are more likely to view a mixture of the two pictures rather than alternating between visual fields. They suggest that people high on Openness “may literally also ‘see’ more possibilities, in that they identify more flexible ways of combining information within basic visual stimuli.” We expect that these findings will generalize across other measures of apophenia and a broad range of visual paradigms. Study 1 aims to extend knowledge of visual processing abnormalities related to the apophenia domain by administering an object detection paradigm that experimentally manipulates perceptual ambiguity.

The current project employs the Fragmented Ambiguous Object Task (FAOT; Olman et al., submitted), an object detection paradigm that presents fractured representations of semantically rich images – objects such as plants, animals, everyday objects, and furniture – and manipulates the degree of ease with which the known object can be seen. FAOT target objects are surrounded by fragmented elements, similar to other visual integration stimuli (Cardin, Friston, & Zeki, 2011; Sassi, Vancleef, Machilsen, Panis, & Wagemans, 2010; Silverstein et al., 2012). FAOT maximizes automatic object processing during top-down visual integration by using complex, meaningful degraded objects that are comparable across low-level features. Tasks with controlled basic visual properties and fragmented object forms activate a network of sensory and frontal brain regions, and elicit behavioral and neural deficits in many psychotic samples (Azadmehr et al., 2013; Butler et al., 2013; Cardin et al., 2011; Doniger, Foxe, Murray, Higgins, & Javitt, 2002; Moritz et al., 2014; Sehatpour et al., 2010; Silverstein et al., 2009; Teufel et al., 2015).

The current study explores how pattern recognition during object detection relates to personality traits relevant to psychotic phenomenology. In addition to two measures of apophenia, MPQ Absorption and BFAS Openness, we include the Personality Inventory for DSM-5 (PID-5). The PID-5 is a more recently developed maladaptive personality measure that includes the domain trait Psychoticism. There is considerable controversy as to whether Psychoticism is a maladaptive analogue of Openness (Chmielewski, Bagby, Markon, Ring, & Ryder, 2014; DeYoung et al., 2012; Knezevic, Savic, Kutlesic, & Opacic, 2017; Suzuki, Samuel, Pahlen, & Krueger, 2015). However, it reliably forms a fifth domain in the structure of personality pathology (Kotov et al., 2017). Personality measures that include more pathological experiences, such as the PID-5, have gained momentum as tools to better capture psychopathology phenotypes within a dimensional model. The heritability and prevalence of subclinical psychotic experiences make psychosis a prime candidate for study under dimensional models (Coleman et al., 1996; Fusar-Poli et al., 2012; Hanssen, Bak, Bijl, Vollebergh, & Os, 2005; E. R. Peters, Joseph, & Garety, 1999; Schürhoff et al., 2003; Tsakanikos & Reed, 2005). Understanding how more extreme variants of perceptual distortions and psychosis proneness correspond with normative personality will advance our understanding of apophenia and sensory processing.

I hypothesize that people with high apophenia will more frequently find meaning in ambiguous stimuli. The pattern is expected to persist across normative and maladaptive personality traits in the apophenia spectrum. This is consistent with previous findings in studies of schizotypy and persons at-risk for psychosis (Partos et al., 2016; Teufel et al., 2015; Uhlhaas et al., 2005; Wallace, 1990). Importantly, convergence across trait measures of apophenia will support the idea that apophenia holds a coherent and consistent relationship with visual processing. Analyses will also probe the differential relationship between Intellect and Openness facets. It is hypothesized that Intellect and intelligence will be negatively correlated with object detection. This pattern is consistent with the opposing influences of positive and disorganized schizotypy that has been reported previously in visual detection tasks (Partos et al., 2016; Teufel et al., 2015; Uhlhaas et al., 2004). The semantic richness of FAOT stimuli is expected to require more extensive top-down processing that might rely on general intelligence and accentuate the effect.

Methods

Participants

Two-hundred seven undergraduate students, ages 18 to 44, completed the Study 1 research protocol. The protocol included administration of an initial version (version 1) of the FAOT behavioral task, and was carried out as part of the University of Minnesota (UMN) undergraduate Research Experience Program (REP). All participants were undergraduate students enrolled in courses offering credit for REP participation at the

UMN, Twin Cities campus. Inclusion criteria were 18 to 60 years of age, fluent in English, an intelligence quotient (IQ) greater than 70, and no immediate health or mental health crisis.

The measures of interest were administered within a larger protocol that seeks to experimentally isolate apophenia from related cognitive processes such as creative achievements, divergent thinking and intellectual ability within a pool of undergraduate volunteers. The protocol consisted of a single research visit, approximately 120-150 minutes long, for which students received one REP point per thirty minutes of participation plus one point for travel time. Participants were recruited through advertisement on the REP website, and in-class announcements by the Principal Investigators (co-PIs: Julia Longenecker and Dr. Bonnie Klimes-Dougan). Research visits were completed in Dr. Colin DeYoung's lab space at UMN, where each participant completed a written, informed consent process. All participants had the capacity to understand the study procedures and provide informed consent. The protocol was approved by the University of Minnesota Institutional Review Board, and all procedures complied with the Declaration of Helsinki.

Measures

The study goal was to identify experimental paradigms that converged with self-report indices of apophenia. Several neuropsychological instruments, experimental paradigms, and personality questionnaires were employed in service of this goal.

<u>Fragmented Ambiguous Object Task, Version 1:</u> FAOT Version 1 contains a pool of 100 images for which participants were asked to respond "yes" if they could see a

known object in the image, and “no” if they could not. Every participant saw all 100 images in random order. Images appeared on an LCD monitor one at a time for 1000 ms, or until the participant made a response (up to 7000 ms), whichever was longer. The task was programmed in PsychoPy2 and viewed on a PC computer running Windows XP from a distance of 133 cm at a subtense of 4.5 degrees.

Following the “yes/no” judgments, participants completed a second task, FAOT Naming. FAOT Naming, which was not included in the current analysis. FAOT Naming presents each image for which the participant previously gave a “yes” response. The participant is asked to identify the object seen in the image by typing it while viewing each image on the screen; they were permitted to skip images if they could not explicitly identify the image. There was no time limit for responses. The total duration of both tasks was approximately 10 minutes per participant.

The FAOT Version 1 images are a subset of the stimuli described in the full methods paper (Olman, et al., submitted). Briefly, FAOT stimuli are degraded representations of objects (384 x 384 pixels) formed by line segments surrounded by uniformly oriented line segments. All line segments were derived from the pictures using a “winner-takes-all” algorithm, as shown in Figure 2. Lines are identically sized and white, contrasting with a solid gray background. Stimuli are comparable on low-level visual stimulus features while the high-level feature of recognition difficulty is allowed to vary: some images contain clearly recognizable objects, some objects are identified by the minority of viewers, and others fall somewhere in between.

Questionnaires: Three self-report questionnaires are the focus of the current research question:

1) the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982)

2) the Personality Inventory for DSM-5 (PID-5; Krueger, Derringer, Markon, Watson, & Skodol, 2012)

3) the Big Five Aspect Scale (BFAS; DeYoung, Quilty, & Peterson, 2007)

Participants completed only the 34 MPQ items that form the Absorption subscale. Absorption has good criterion and convergent validity (Patrick, Curtin, & Tellegen, 2002; Auke Tellegen & Atkinson, 1974b). MPQ Absorption questions were interspersed with PID-5 items for administration purposes. Absorption was calculated as a sum of all 34 items, with missing items prorated. The PID-5 is a self-report measure of maladaptive personality traits, for which participants completed the full set of 220 items. PID-5 scales were scored using empirically derived factors described in the seminal manuscript and presented as mean values (Krueger et al., 2012). BFAS is a normative personality scale which derives the Five Factor Model, as well as the two aspects subordinate to each of the five personality traits. BFAS scales were calculated as mean values. Scales with more than 20% missing data on any of the questionnaires were not scored.

Cognitive Measures: Full-scale Intelligence Quotient (IQ) was estimated using prorated scaled scores of the Block Design, Matrix Reasoning, Vocabulary, and Similarities subtests of the Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler, 2008).

Statistical Analysis

Three linear regression analyses were carried out to test whether the three self-report measures of apophenia predicted a stronger propensity to respond “yes” in the FAOT experimental paradigm. For all analyses, FAOT “Yes” responses as a proportion of total responses was the dependent variable. The primary analysis tested whether BFAS Openness predicted FAOT behavioral performance. In order to ensure that the relationship was the result of variance unique to the Openness aspect rather than that shared with Intellect, both BFAS Intellect and Openness were included as independent predictors. The second analysis tested whether MPQ Absorption predicted FAOT behavioral performance. Since the MPQ does not include a subscale to account for intellect, WAIS-IV estimated full scale IQ was included alongside MPQ Absorption as an independent predictor. The third and final analysis tested whether PID-5 Psychoticism predicted FAOT performance. As with the previous model, WAIS-IV IQ was also included as an independent predictor. Collinearity levels were acceptable in all statistical models based on VIF (<5) and tolerance (> 0.2) values.

Results

Study 1 sought to characterize an experimental paradigm that measures “apophenia,” or the tendency to find meaning in random or coincidental occurrences. This goal was carried out in the normative population, a group of undergraduate volunteers, in order to establish motivation for further investigation in a clinical sample. The central hypothesis was that performance on a visual object detection task would be consistently, positively associated with normative and maladaptive personality traits of apophenia.

Table 1. Sample Characteristics of Study 1 Undergraduate Participants. *The 191 undergraduate volunteers described in this table had complete data and were included in Study 1 analyses. MPQ Absorption is reported as a sum with range 0-136. PID-5 scores are means ranging 0 ('Very False or Often False') to 3 ('Very True or Often True'). BFAS scores are means ranging 1 ('Strongly Disagree') to 5 ('Strongly Agree').*

		N (%)
N (% Male)		191 (37%)
Ethnicity		
	White	154 (81%)
	Black	8 (4%)
	Asian	18 (9%)
	Hispanic	5 (3%)
	Native American	2 (1%)
	Other	3 (2%)
		x (SD)
Age		21.13 (4.84)
WAIS-IV Estimated IQ		115.77 (17.39)
BFAS		
	Neuroticism	2.85 (0.53)
	Agreeableness	3.37 (0.66)
	Conscientiousness	3.38 (0.48)
	Extraversion	3.43 (0.47)
	Openness/Intellect	3.44 (0.41)
PID-5		
	Negative Affect	1.26 (0.38)
	Detachment	0.66 (0.38)
	Antagonism	0.81 (0.47)
	Disinhibition	1.09 (0.36)
	Psychoticism	0.8 (0.52)
MPQ		
	Absorption	36.93 (18.93)

Of the 207 participants who completed the overarching research protocol, eight were missing FAOT data. An additional eight participants were excluded based on their FAOT performance for responding only "yes" or making responses for less than 75% of trials. A remaining twelve were missing BFAS data. As a result, the BFAS analyses included 179 participants, while the PID-5 and MPQ analyses included 191 participants (see Table 1).

Table 2. FAOT Performance as Predicted by BFAS Openness in Hierarchical Regression. *Step 2 of a hierarchical regression examining FAOT behavioral performance in the Study 1 undergraduate sample, in which the BFAS aspect Openness was added as a predictor, accounted for the most variance in FAOT performance. Participants higher on the BFAS aspect Openness endorsed more of the FAOT stimuli as meaningful, after controlling for age, gender, and variance shared with the aspect Intellect.*

	β	**b**	**SE**	**t**	**95% CI**	**p-value**
Step 1						
Intercept		*0.37*	*0.049*	*7.56*	*[0.274, 0.467]*	*0.000*
Age	0.15	0.03	0.014	1.98	[0.000, 0.055]	0.049 *
Gender	0.05	0.02	0.029	0.69	[-0.037, 0.077]	0.489
BFAS Intellect	0.13	0.03	0.014	1.74	[-0.003, 0.052]	0.083
Step 2						
Intercept		*0.38*	*0.049*	*7.85*	*[0.287, 0.480]*	*0.000*
Age	0.14	0.03	0.014	1.83	[-0.002, 0.053]	0.070 †
Gender	0.03	0.01	0.029	0.42	[-0.045, 0.069]	0.676
BFAS Intellect	0.07	0.01	0.015	0.84	[-0.017, 0.042]	0.402
BFAS Openness	0.17	0.03	0.015	2.15	[0.003, 0.062]	0.033 *

† = threshold of significance (0.05≤p<0.09); *p<0.05; ** p<0.01

I hypothesized that participants' rates of "yes" responses to FAOT stimuli would be positively correlated with self-report indices of apophenia, including the BFAS Openness-to-Experience aspect, the MPQ Absorption subscale, and PID-5 Psychoticism. I expected these relationships to be accentuated by controlling for BFAS Intellect or

WAIS-IV estimated full-scale IQ, and a weak, negative correlation between measures of intelligence (i.e., IQ and Intellect) and object detection. I observed the expected main effects on each of the three apophenia personality measures, but did not see the predicted effects of Intellect or intelligence.

Table 3. FAOT Performance as Predicted by BFAS Domains in Hierarchical Regression. *The Openness/Intellect domain significantly predicted higher endorsement of FAOT images even when the full normative Five Factor Model was included in the analysis. Conscientiousness emerged as an additional predictor of FAOT; those high in Conscientiousness saw known objects in fewer images.*

	β	**b**	**SE**	**t**	**95% CI**	**p-value**
Intercept		*0.39*	*0.048*	*8.10*	*[0.296, 0.487]*	*0.000*
Age	0.07	0.01	0.015	0.94	[-0.015, 0.042]	0.348
Gender	0.01	0.01	0.029	0.18	[-0.052, 0.062]	0.859
Openness/Intellect	0.22	0.04	0.015	2.77	[0.012, 0.07]	0.006 **
Neuroticism	-0.02	0.00	0.015	-0.22	[-0.033, 0.026]	0.829
Agreeableness	0.06	0.01	0.015	0.71	[-0.019, 0.041]	0.477
Conscientiousness	-0.23	-0.04	0.015	-2.83	[-0.071, -0.013]	0.005 **
Extraversion	0.04	0.01	0.016	0.40	[-0.025, 0.038]	0.692

† = threshold of significance (0.05≤p<0.09); *p<0.05; ** p<0.01

First, BFAS Openness significantly predicted the proportion of FAOT images seen as meaningful ($\beta = 0.17$; $p<0.05$; see Table 2 and Figure 3). Step 2 of the statistical model, in which BFAS Openness was added, accounted for significantly more of the variance in FAOT responses than a Step 1 ($\Delta R^2 = 0.03$; $R^2_{adj} = 0.024$). In contrast to our expectations, BFAS Intellect loaded weakly *positively* on FAOT scores. We additionally explored the interaction between Intellect and Openness as a predictor, but there was not a significant change in R values when the interaction term was added to the model. Thus, a moderation effect was not observed. In order to ensure that the main effect was specific to the O/I domain, we also computed a regression that included all five BFAS factors. As shown in Table 3, a positive correlation between FAOT and O/I was present at the domain level (β = 0.22; $p<0.05$). Additionally, we found a negative association between FAOT and Conscientiousness (β = -0.23; $p<0.05$).

Table 4. FAOT Performance as Predicted by PID-5 Psychoticism in Hierarchical Regression. *The maladaptive personality trait PID-5 Psychoticism was positively associated with better detection of FAOT objects. The correlation with FAOT is consistent across normative and maladaptive measures at the extreme end of the Openness/Intellect simplex.*

	β	b	SE	t	95% CI	p-value
Step 1						
Intercept		*0.36*	*0.047*	*7.66*	*[0.266, 0.45]*	*0.000*
Age	0.17	0.03	0.013	2.40	[0.006, 0.058]	0.018 **
Gender	0.07	0.03	0.028	0.95	[-0.028, 0.081]	0.343
WAIS-IV IQ	0.11	0.02	0.013	1.50	[-0.006, 0.046]	0.135
Step 2						
Intercept		*0.31*	*0.048*	*6.59*	*[0.22, 0.408]*	*0.000*
Age	0.19	0.04	0.013	2.75	[0.01, 0.062]	0.007 *
Gender	0.14	0.05	0.028	1.90	[-0.002, 0.109]	0.059 †
WAIS-IV IQ	0.09	0.02	0.013	1.27	[-0.009, 0.042]	0.207
PID-5 Psychoticism	0.24	0.05	0.014	3.27	[0.018, 0.072]	0.001 **

† = threshold of significance ($0.05 \leq p<0.09$); $*p<0.05$; $** p<0.01$

Second, FAOT responses were significantly predicted by the Psychoticism domain on the PID-5 maladaptive personality questionnaire (β = 0.24; $p<0.01$; see Table 4 and Figure 3). Step 2 predicted FAOT scores more strongly than Step 1 ($\Delta R^2 = 0.05$; $R^2_{adj} = 0.07$). Like BFAS Intellect, WAIS-IV IQ was weakly positively correlated with FAOT performance, and the interaction between IQ and Psychoticism was excluded from the model due to lack of predictive power. As with BFAS, we tested whether the effect was upheld when all five PID-5 domains were included in a model. Indeed, the positive relationship between FAOT scores and Psychoticism remained (β = 0.25; $p<0.05$; see Table 5) in addition to an association with Disinhibition (β = 0.26; $p<0.05$). High Disinhibition is equivalent to very low (i.e., negative) Conscientiousness. Thus, a negative Conscientiousness coefficient is consistent with a positive Disinhibition coefficient. The results consistently demonstrate a relationship between visual detection and the normative and maladaptive range of two personality domains.

Table 5. FAOT Performance as Predicted by PID-5 Domain Traits in Hierarchical Regression. *Multiple PID-5 Domain Traits predicted FAOT behavioral performance. Consistent with findings using the normative personality measure, BFAS, Psychoticism and Disinhibition were associated with FAOT scores. High levels of psychosis-proneness appears related to greater pattern detection in fragmented visual stimuli. The effect of Disinhibition is a novel finding that is suspected to be related to fastidiousness and restraint in response patterns.*

	β	**b**	**SE**	**t**	**95% CI**	**p-value**	
Intercept		*0.31*	*0.052*	*6.04*	*[0.21, 0.414]*	*0.000*	
Age	0.11	0.02	0.014	1.58	[-0.005, 0.048]	0.117	
Gender	0.14	0.05	0.031	1.70	[-0.008, 0.113]	0.091	
WAIS-IV IQ	0.09	0.02	0.013	1.26	[-0.009, 0.041]	0.210	
Psychoticism	0.25	0.04	0.018	2.43	[0.008, 0.08]	0.016	*
Negative Affect	-0.06	-0.01	0.015	-0.68	[-0.04, 0.019]	0.496	
Antagonism	-0.11	-0.02	0.017	-1.21	[-0.054, 0.013]	0.229	
Disinhibition	0.26	0.05	0.015	3.11	[0.017, 0.075]	0.002	**
Detachment	-0.04	-0.01	0.015	-0.47	[-0.036, 0.022]	0.642	

† = threshold of significance ($0.05 \leq p < 0.09$); * $p<0.05$; ** $p<0.01$

Lastly, MPQ Absorption was the strongest predictor of FAOT performance (β = 0.33; $p<0.001$; see Table 6 and Figure 3). Adding Absorption in Step 2 accounted for significantly more variance in FAOT responses than age, gender, and WAIS-IQ had in Step 1 ($\Delta R^2 = 0.10$; $R^2_{adj} = 0.13$). Age significant predicted FAOT in a positive direction

Table 6. FAOT Performance as Predicted by MPQ Absorption in Hierarchical Regression*. Of the three personality measures, Absorption was the most strongly associated with FAOT. Absorption accounted for the largest portion of FAOT variance (Step 2) such that those with high Absorption found more images to be meaningful, even after controlling for age, gender, and IQ (Step 1).*

	β	b	SE	t	95% CI	p-value	
Step 1							
Intercept		*0.36*	*0.047*	*7.66*	*[0.266, 0.45]*	*0.000*	
Age	0.17	0.03	0.013	2.40	[0.006, 0.058]	0.018	**
Gender	0.07	0.03	0.028	0.95	[-0.028, 0.081]	0.343	
WAIS-IV IQ	0.11	0.02	0.013	1.50	[-0.006, 0.046]	0.135	
Step 2							
Intercept		*0.32*	*0.045*	*7.21*	*[0.235, 0.412]*	*0.000*	
Age	0.17	0.03	0.013	2.52	[0.007, 0.057]	0.013	*
Gender	0.12	0.05	0.026	1.79	[-0.005, 0.1]	0.076	†
WAIS-IV IQ	0.05	0.01	0.013	0.70	[-0.016, 0.034]	0.487	
MPQ Absorption	0.33	0.06	0.013	4.72	[0.036, 0.087]	0.000	**

† = threshold of significance (0.05≤p<0.09); *p<0.05; ** p<0.01

in both steps of the model (β = 0.17; $p<0.05$). An Absorption x IQ interaction term was eliminated from the model because moderation was not significant and reduced the adjusted R^2 value. Absorption and Psychoticism are closely related constructs (*r*=.80), but Absorption appears to more closely relate to visual integration required of the FAOT, supporting the theory that individuals with high apophenia extrapolate patterns from sensory experiences at a heightened rate.

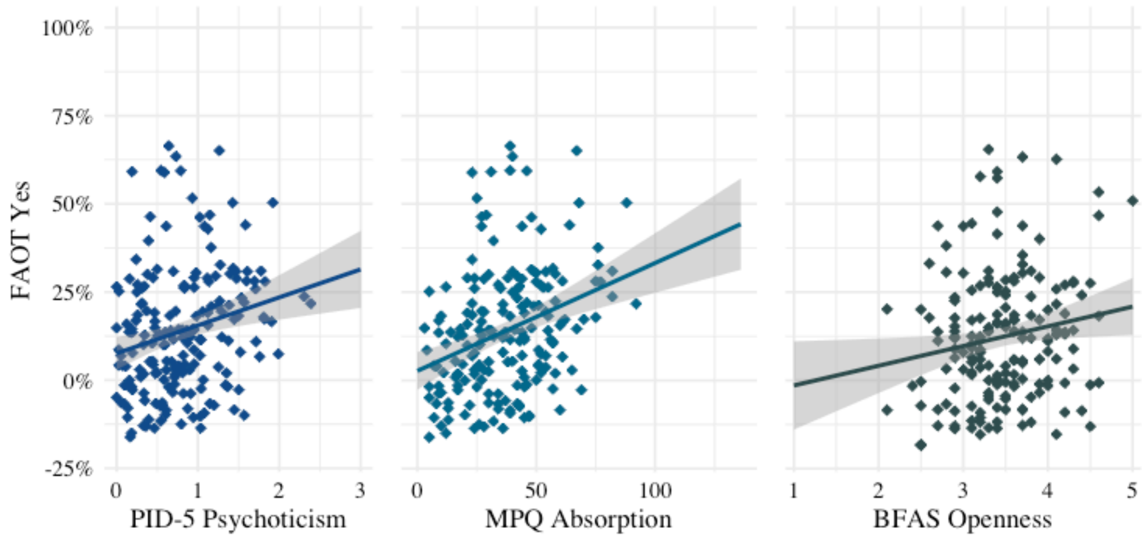

Figure 3. Apophenia and Psychosis-Proneness Traits Predict Image Detection. *All three personality measures of apophenia significantly predicted higher FAOT scores (i.e., more objects detected). The relationship was strongest between MPQ Absorption and FAOT (middle pane). Note that the y-axis represent FAOT scores after correction for age and gender; therefore, adjusted values extend below the actual range of 0-100%.*

Discussion

The current study is one of few to investigate whether trait-level apophenia reflects altered interpretation of sensory input. The aim was to test the relationship between a visual object detection paradigm and personality traits that reflect apophenia and psychosis-proneness. Consistent with the study hypotheses, there was a reliable association with visual task performance across normative and maladaptive traits. BFAS Openness, MPQ Absorption, and PID-5 Psychoticism were positively correlated with FAOT object detection. The second hypothesis that BFAS Intellect and intelligence would show a negative correlation with object detection, was not supported. Neither Intellect nor intelligence moderated the effect of apophenia traits on object detection, as has been reported previously (Partos et al., 2016).

Importantly, the findings extend definitions of apophenia into the realm of vision. Participants who self-report experiencing the world more openly appear more sensitive to patterns in visual stimuli. The results provide needed empirical evidence that people with high apophenia may, in fact, perceive the world more flexibly. In many ways, the results seem straight-forward and expected. While apophenia embodies self-report of sensory distortion and sensitivity, Antinori and colleagues are the only researchers to test the relationship between Openness and a visual task. Study 1 shows that high apophenia reflects alterations across multiple visual paradigms. Effect sizes are typical as compared to most social psychology research (Richard, Bond Jr., & Stokes-Zoota, 2003) and those reported by Antinori et al. (2018) for binocular rivalry. The current results were robust across multiple assessment tools in a visual realm other than binocular rivalry; all three personality measures correlated with task-based object detection performance. The stability of findings across multiple personality measures and visual paradigms suggests that the extreme end of the Openness/Intellect simplex is broadly associated with visual processing.

Furthermore, the results suggest that more pathological traits related to psychosis-proneness similarly relate to visual processing. PID-5 Psychoticism, a trait measure related to psychotic phenomenology, also was positively correlated with greater object detection. The analyses were not meant to test how Psychoticism fits into the structure of personality. However, there was considerable overlap between Psychoticism and the other two personality traits (BFAS: $r = 0.21$; MPQ Absorption: $r = 0.81$), and similar predictive power for object detection performance. Thus psychotic traits, at least at the levels reported in the general population, appear similarly related to flexible interpretation of visual stimuli. Maladaptive scales like Psychoticism may be helpful for extending research of individual differences in visual processing to clinical populations. Apophenia might be an inappropriate or insufficient assessment of pathological sensory experiences. Including normative and maladaptive traits in future research of vision in clinical populations will help tease apart the boundaries of the relationship between these traits and visual behaviors.

We had hypothesized that the shared variance between apophenia and Intellect would be particularly important for predicting visual processing. Past studies have shown that there is a weak, negative correlation between apophenia and intelligence, and that disorganized schizotypy moderates the correlation between positive schizotypy and blurred picture identification (DeYoung et al., 2012; Partos et al., 2016). Instead, our sample showed a positive correlation between Absorption and intelligence ($r = 0.19$), and no significant main effect or moderation of intelligence in any of the statistical models. One possibility is that the intelligence and Intellect levels of the current sample were too high to achieve a moderation effect. The Study 1 mean IQ is shifted one standard deviation above WAIS-IV population norms, typical of undergraduate samples. The IQs of undergraduate samples may form a restricted range, particularly with respect to below average intelligence (here conceptualized as similar to high disorganized schizotypy), that does not extend to the range observed by Partos and colleagues. Another possibility is that intelligence does not play a role in visual integration after covariance with apophenia has been removed. Carrying out the Study 1 methods in an at-risk or psychiatrically affected population will allow us to examine the relationship between apophenia and intelligence across a more expansive range of scores. Either way, the current study and related literature suggest visual integration is not strongly influenced by general intelligence, but rather specifically related to the apophenia domain. Identifying specific areas of cognition is important to research of severe mental illness in which deficits are often generalized and difficult to isolate.

It remains to be seen what aspects of visual processing relate to apophenia. Research has shown that apophenia is related to flexible thinking in binocular rivalry and object detection. Both tasks utilize images of semantically elaborate, real-life objects. FAOT relies on a hierarchy of visual processing, from contrast detection to grouping elements into a form to understanding the meaning of the object. The design of Study 1 does not distinguish between those processes. Future studies that include neuroimaging or electrophysiological measures can isolate the neural processes driving increased object detection. In particular, it would be informative to know whether apophenia is more closely associated with basic feature processing in the visual stream, or higher-order matching of visual input to existing knowledge.

FAOT was designed to minimize variation in low-level properties. However, a limitation of the current sutdy is that a portion of the intended image set was mistakenly replaced by images from an earlier stage of task development. Thus, the image set in FAOT version 1, used in the current study, differs from that in FAOT version 2 used in Study 2. Furthermore, there is the possibility that version 1 images were not matched on low-level features as thoroughly as in later versions of the paradigm. Nonetheless, the findings strongly support a link between apophenia and visual perception. Further research can tease apart the exact contributions of stimuli features. In addition, future studies can examine the extent to which these patterns generalize in psychiatric samples and across other sensory modalities.

Chapter 3: Associations Between Personality, Object Detection, and Event-Related Potentials in Psychotic Disorders

Study 2

In the present study, I firstly seek to replicate our Study 1 findings in a clinical population that includes persons with schizophrenia spectrum or bipolar I disorder, first-degree relatives, and psychiatrically unaffected controls. Research of object detection in psychotic spectrum disorders has chiefly relied on between-groups comparisons. The heterogeneity within diagnostic categories may obscure meaningful relationships between visual disturbances and personality domains like apophenia that cross diagnostic boundaries. By employing a clinical sample, Study 2 will test the relationship between object detection and the extreme ends of the apophenia and intellect domains. Secondly, I will examine the timing of ERPs involved in an object detection task that employs fragmented images with high semantic value. Between-group and individual differences analyses will be carried out to explore how current neurobiological knowledge of visual perception in psychosis may connect to findings in personality research. Examining visual anomalies across self-report, behavioral, and physiological units of analysis, will tease apart contributions of familial liability, disease state, and personality trait.

The extensive neural network that supports object detection has been characterized in neuroimaging with respect to top-down and bottom-up influences. Electrophysiological studies have largely focused on bottom-up influences from basic dorsal and ventral streams. To provide more context for the second aim of Study 2, I briefly review ERPs involved in object detection, including preliminary findings of top-down ERPs from frontal scalp sites.

Psychophysiology of Object Detection

Object detection paradigms reliably demonstrate three event-related potentials (ERPs) that map onto the visual neural network: P1, N1, and "closure negativity" (N_{CL}). In schizophrenia, P1 and N_{CL} are generally attenuated, while the earlier ventral response characterized by N1 remains intact (Foxe et al., 2005; Sehatpour et al., 2010; Silverstein & Keane, 2011). While ERPs cannot explicitly distinguish between feedforward and feedback communication, they are informed by existing knowledge of neural structure and response. The timing provided by EEG recordings adds a complimentary element by which to advance theories of complex networks.

P1 is a dorsal positive voltage deflection broadly linked to selective attention, arousal, and stimulus characteristics. Of the three components, P1 represents the earliest disruption in the time course of contour integration. It should also represent the initial feed-forward processing of external sensory stimuli via the dorsal visual stream. It follows that early deficits in P1 may reflect abnormalities in processing sensory input, supporting one theoretical orientation of visual neural networks. P1 abnormalities in schizophrenia could substantiate circular inference algorithm assertions: attenuation of an early visual sensory pathway, likely reflecting reduced inhibitory neural activity, precedes behavioral performance deficits. The visual N1 referred to here refers to a negative amplitude deflection that peaks at approximately 160ms and indexes discriminative processes in the ventral pathway, such as those required to distinguish the orientation of separate visual elements forming an outline (Vogel & Luck, 2000).

N_{CL} is specialized to tasks that require visual closure of an object form (Doniger, Foxe, Murray, Higgins, & Javitt, 2002). It is a negative amplitude deflection thought to reflect the meeting of feed-forward percepts and feedback predictions from higher level brain regions (Bar et al., 2006; Kim, Biederman, Lescroart, & Hayworth, 2009; Shpaner et al., 2013). N_{CL} dipoles have been source localized to fusiform gyrus within LOC (Butler et al., 2013). Amplitude is more negatively deflected for unscrambled versus scrambled images, even in the absence of P1 and N1 condition effects (Shpaner et al., 2013; Yeap et al., 2006). N_{CL} is sensitive to both simple and complex contours (Doniger et al., 2000; Murray et al., 2006). Early disruptions of sensory input may exert downstream effects which cause mismatch between feed-forward and feedback neural input at the time of N_{CL}, and result in behavioral performance deficits in schizophrenia (Grill-Spector, Kourtzi, & Kanwisher, 2001).

Temporal precision, such as that offered by EEG, will provide further information about how frontal activation may influence aspects of the visual network. Disruptions at frontal scalp, as observed in a few ERP studies, may exert top-down control that modulates ventral P1 and N_{CL} response (Foxe et al., 2005; Sehatpour et al., 2010; Yeap et al., 2006). An anterior ERP component has been identified in a handful of studies employing paradigms that display complex meaningful stimuli (i.e., more semantically coherent than basic shapes). Two candidate components arise from these studies: 1) $P1^F$, a positive deflection preceding P1 at around 120ms post-stimulus; and 2) N^F_{CL} a negative voltage deflection preceding N_{CL} approximately 250ms post-stimulus. Both appear bilaterally at anterior electrode sites and have been observed during post-hoc inspection of ERP waveforms (Doniger et al., 2002; Foxe et al., 2005; Ishizu, 2013; Sehatpour et al., 2010; Yeap et al., 2006). $P1^F$ timing is consistent with research showing that prefrontal activations can be rapid and emerge prior to 100 ms post-stimulus during visual stimulation (Kveraga et al., 2007). If $P1^F$ is reliably elicited during object detection and disrupted in schizophrenia, it may represent overexertion of prior knowledge. That is, frontal brain regions may make a "first guess" by assigning semantic meaning to percepts. The guess is more likely to be errant if initiated too early when sensory information has not been refined by iterations through the hierarchy; this low signal-to-noise ratio preceding refinement may be represented by amplified $P1^F$. Earlier prefrontal involvement could precipitate dorsal and ventral disruptions. Replication of $P1^F$ that predicts dorsal P1 attenuation would challenge circular inference models. On the other hand, N^F_{CL} fits well into circular inference conceptualizations in that frontal feedback occurs after initial sensory processing. Sensory information might flow up the dorsal (P1) and ventral (N1) streams as feedback is transferred from frontal areas (N^F_{CL}) to the LOC (N_{CL}). Initial fMRI analysis of FAOT in the same clinical sample shows greater activation of the prefrontal cortex, LOC, and primary visual cortex regions during the meaningful condition, supporting the proposed hypothesis that the task will elicit occipital and frontal activation. Frontal regions are implicated in prior knowledge theories, in which relevant conceptual and associate knowledge would be selected and coordinated with sensory input feedback to the visual pathways. Yet, frontal components have not been incorporated into ERP models of contour integration. The timing of anterior scalp activity would give insight into the initial sources of neural disruption and subsequent behavioral consequences. Through an analysis of ERPs, I will contrast the timing of anterior and occipital scalp potentials involved in visual integration of fragmented, meaningful stimuli in FAOT by first comparing the participant groups then individual differences in apophenia.

Neural Correlates of Apophenia

There is a paucity of research on the neural basis of personality traits related to apophenia. The studies that have been carried out have established meaningful associations between neurobiological variables and apophenia in community samples. The P1 ERP at parieto-occipital scalp sites seems to be preferentially disrupted in psychiatrically healthy people with high positive schizotypy (Bedwell, Chan, Trachik, & Rassovsky, 2013; Koychev, El-Deredy, Haenschel, & Deakin, 2010). The findings are consistent with early disturbances in the dorsal stream like those seen in persons with schizophrenia. It has also been shown that “leaky” sensory gating in the earliest periods of sensory processing might support the unique associations that lead to divergent thinking (Zabelina, O’Leary, Pornpattananangkul, Nusslock, & Beeman, 2015). Disruptions in ERP components over dorsal regions in the first 100ms of visual processing suggests that feedforward communication is abnormal. In contrast, others have suggested that schizotypy is related to mental imagery or a superior ability to organize experiences as opposed to altered sensory processing (Maróthi & Kéri, 2018; Mohr & Claridge, 2015). This would be more consistent with disrupted higher order processing, such as feedback communication that delivers predictions based on prior knowledge. Both sources of abnormality require further study. It is possible that, as in behavioral research, different aspects of schizotypy differentially relate to visual processing. Allen & DeYoung have suggested that Intellect is related to drawing associations in abstract or semantic information, while Openness is related to pattern discovery in perceptual material (Allen & DeYoung, 2016). Thus, traits of apophenia may be more related to feedforward sensory processing, while intelligence may modulate feedback predictions. The findings to-date suggest that similar electrophysiological abnormalities in visual processing are present in normative and clinical populations, and that these brain-based irregularities may be associated with dimensional traits of apophenia.

The link to visual abnormalities that cross traditional diagnostic classifications is further examined by comparing ERPs to personality measures of apophenia. The last set of analyses in Study 2 test a highly exploratory theory that disruption of feedback and feedforward communication are uniquely related to apophenia traits and intelligence, respectively.

Aims

As part of a larger, ongoing study of visual perception in psychosis I will:

Aim 1. Establish a) whether psychosis affects identification of fragmented objects within visual background noise; and b) if traits of disrupted sensory experiences, as measured by MPQ Absorption, and intellectual performance are associated with enhanced object detection. Based on the visual integration literature in schizophrenia, I expect to find a significant performance difference between participants with psychotic disorders and healthy controls. Relatives are expected to exhibit intermediate levels of performance. With respect to the trait-based analysis, I hypothesize that high levels of apophenia will be positively associated with object detection. Furthermore, the relationship between apophenia and object detection performance will be moderated by intellectual ability so that persons with high apophenia and low intelligence will show an object detection performance deficit.

Aim 2. Test the hypotheses that a) an ERP component reliably occurs at anterior scalp sites during perception of fragmented outlines within visually noisy backgrounds; b) scalp voltage if ERPs that are well-established in the visual integration literature and the anterior components differs between participants with psychotic disorders, first-degree biological relatives, and healthy control subjects; and c) traits of apophenia, as measured by Absorption, account for unique variance in visual integration ERP amplitudes across all participants, above and beyond categorical diagnostic group. The existence and timing of the anterior component will determine whether feedback may precede P1, perhaps exerting downstream effects that attenuate dorsal stream response. While findings will not definitively show feed-forward disruptions, the neuroanatomy and timing make it reasonable that $P1^F$ is feedback that affects the subsequent P1 response. Later frontal response consistent with N^{F}_{CL} timing, would suggest that dorsal visual input is disrupted independent of early prefrontal feedback, in line with circular inference theories. Considering group differences will test whether select pathways are disrupted in psychotic spectrum disorders. P1 and N_{CL} are expected to be attenuated, while N1 is expected to be intact, consistent with past findings in the clinical literature.

Evidence in unaffected populations suggests visual processing abnormalities reflect a spectrum of perceptual tendencies. Some theoretical orientations allege disrupted sensory input, while others posit it is primarily a failing of applications of prior knowledge. An association between Absorption and dorsal components (i.e., P1) would be suggestive of decreased inhibition of feed-forward sensory input. This hypothesis aligns with prior research showing superior visual perception associated with apophenia, and ties perceptual aberrations to a highly established, psychometrically strong personality trait measure (Tellegen & Atkinson, 1974b). An association between Absorption and an anterior component would suggest neural network disruptions are more governed by anomalies in prior knowledge.

Investigating the timing of psychophysiological components, particularly those localized outside the sensory cortex, will complement existing knowledge derived from functional imaging studies. The current study considers behavioral and psychophysiological measures between traditional diagnostic groups then extends the investigation to dimensional traits that capture self-reported abnormal perceptual experiences. Including multiple personality traits related to the Openness domain may further our understanding of how object detection performance and the related psychophysiological responses vary across psychiatric, at-risk, and normative populations.

Methods

Participants

One hundred seventy-two participants were enrolled in the present study, including persons with a schizophrenia spectrum disorder (n= 47), persons with bipolar I affective disorder (n= 41), first-degree biological relatives of persons with schizophrenia (n= 26), first-degree biological relatives of persons with bipolar disorder (n= 22), and healthy controls (n= 36). One individual with schizophrenia was excluded for a current opioid dependence at the time of clinical interview. All those with a psychiatric diagnosis were stable outpatients recruited from the Minneapolis Veterans Affairs Health Care System (VAHCS) and mental health centers in the community. Relatives and healthy controls were recruited through community advertisements and registries consisting of past participants who indicated they wanted to be contacted for future research. Relatives and persons with schizophrenia were also recruited within family units (i.e., asked if other family members might be interested in contacting us to participate). All potential participants were screened via telephone; those that appeared to meet study criteria were invited to participate in person. All participants completed an informed consent process in accordance with the Declaration of Helsinki. The University of Minnesota and Minneapolis VAHCS Institutional Review Boards both provided approval before the study commenced.

All participants underwent a psychodiagnostic evaluation that includes a structured clinical interview (SCID) to assign a Diagnostic and Statistical Manual of Mental Disorders, Fourth edition, Text Revision (DSM-IV-TR) diagnosis (American Psychiatric Association, 2000; First, Spitzer, Gibbon, & Williams, 1997). Participants without a primary psychotic disorder (i.e., relatives and controls) additionally completed the Structured Interview for Schizotypy to assess for Cluster A personality traits and disorders (Kendler, Lieberman, & Walsh, 1989). The clinical interviewer rated current symptomatology of all participants using the 24-item version of the Brief Psychiatric Rating Scale (BPRS; Lukoff, Liberman, & Nuechterlein, 1986). For those with a schizophrenia spectrum diagnoses, the interviewer also rated current symptoms on the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1983) and the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984). Final diagnostic decisions were made through consensus of at least two trained, clinical staff other than the interviewer.

All participants are native English speakers, 18 to 60 years old, with normal or corrected hearing and vision, and intelligence quotient (IQ) greater than 70. All participants had the capacity to understand the study procedures and provide informed consent. Persons with a legal guardian at the time of recruitment were not allowed to participate. Relatives must have a first-degree biological relation to a person with a confirmed schizophrenia spectrum diagnosis through the diagnostic procedures outlines above; for each relative, the diagnosis of the family member with a schizophrenia spectrum disorder was established by our research staff rather than third-person report.

Any participant with history of organic or neurological deficit, or intellectual disability is excluded. Patients and controls are excluded for substance abuse or dependence within the past six months, electroconvulsive therapy (ECT), epilepsy, diagnosed seizure disorder, history of stroke, neurological condition, other uncontrolled medical conditions likely to affect brain functioning (e.g., untreated thyroid condition), or head injury resulting in fractured skull or more than 30-minutes unconscious. Healthy controls are excluded for a history of primary psychotic disorder, hypomania, anti-psychotic medication use, current or past depressive episodes, ADHD or learning disability, Cluster A personality traits or diagnoses, or family history of bipolar or psychotic disorder.

The data for this research was be collected through a larger, funded grant (#IO1CX000227; PI: Scott Sponheim). Participants initially completed a day of detailed clinical assessment for which they were compensated $60 from Dr. Sponheim's grant funds. They then completed a one-day EEG session for which they were compensated $80. Participants also completed a third day of magnetic resonance imaging, which was not included in the current analysis. At times, individual participants needed longer than average to complete procedures; in these instances, compensation was provided commensurate to the time and study procedures. Recruitment and clinical visits began in Spring 2015 in Dr. Sponheim's laboratory. Recruitment was closed April 2018. Electrophysiological data collection began October 2015 and will continue through summer 2018 until all recruited participants have the opportunity to complete the full study. The recruitment rate was consistent with prior grants completed by Dr. Sponheim's laboratory.

Measures

Fragmented Ambiguous Object Task (Version 2) Behavioral Administration: In the current study, two variations of Fragmented Ambiguous Object Task (FAOT; Olman, et al., submitted) Version 2 were administered: one behavioral task in which participants judge whether there is a known object in the image, and during EEG recording in which participants made size judgments about the objects. FAOT Version 2 stimuli are identical for both the behavioral and EEG administrations.

Stimuli are degraded representations of objects (384 x 384 pixels) formed by line segments surrounded by uniformly oriented line segments. All line segments were identically sized and white, contrasting with a solid gray background. The stimulus design controls for low-level visual stimulus features: each image is comparable in number of white and gray pixels, number of line segments, orientation distribution, and number of line terminations. The high-level feature of recognition difficulty forms a continuum whereby some images contain clearly recognizable objects, some objects are identified by the minority of viewers, and others fall somewhere in between. The task used in the current study is Version 2, which includes 217 images ranging in ease of recognition. All task design procedures are described in detail by Olman, et al. (submitted). Briefly, the stimuli were formed through an automated program that generated fragmented representations of single objects found in publicly available image databases. A group of raters viewed and rated the utility of the initial pool of 718 candidate images formed through the automated process. Initially, the process resulted in FAOT Version 1, which was piloted in Study 1 in an undergraduate sample. Further refinement of the stimuli resulted in the 217 images included in Version 2 used in the current study. Across each condition, there is an even distribution of wide and narrow width images. The controlled low-level stimulus characteristics in combination with the manipulation of recognition ease allows exploration of low- and high-level object detection processes.

The behavioral version was administered during the initial clinical assessment visit in pre-designated laboratory space at the Minneapolis VA Healthcare System. Participants viewed 100 images randomly selected from the larger pool of 217 images. For each image, participants indicated whether they could see a known object in the image ("yes"/"no"), as quickly as possible. The task was programmed in PsychoPy2 and viewed on an Apple computer from a distance of 133 cm at a visual angle subtense of 4.5 degrees. Participants viewed stimuli for 1000 ms, or until they made a response (up to 7000 ms), whichever was longer. After completing the "yes"/"no" judgments, participants completed a second task in which the identified the images for which they previously gave "yes" responses, which was not used in the current analysis. Responses were typed while viewing each image on the screen; there was no time limit for responses. The total duration of both tasks was approximately 10 minutes. This version of the FAOT assessed individual participants' tendency to distinguish contours in each image, as well as the accuracy of those responses. Task design was identical to that in Study 1, though the image set differed.

Behavioral performance was quantified by the total number of "yes" responses, calculated as a proportion of total responses, to measure the ease with which participants saw objects in the stimuli. FAOT Proportion Yes is meant to quantify initial detection of an object, which occurs before one is able to identify or name the object and relies on different cognitive processes.

An additional metric, d-prime (d'), was explored in follow-up analyses to verify whether response patterns differed based on the ease of recognition to particular images. D' is considered a metric of response conventionality (Snodgrass & Corwin, 1988). It incorporates both 'hits' and 'false alarms.' D' was used to compare each individual's responses to the expected pattern based on the full sample. The overall recognition rate was calculated for each image using the full set of FAOT behavioral data (n=141), after excluding participants with low response rates (<75% of images) or those with clear response bias (all 'Yes' or all 'No' responses). The images were categorized based on quartiles in the recognition rate distribution. The first quartile contained the 53 most frequently recognized images (>60% recognition rate); these images were those we expected most participants would respond yes to and were considered potential 'hits'. The Hit Rate was defined as:

$$HR = \frac{Hits + 0.5}{Total\ Meaningful\ Stimuli + 1}$$

Each individual received a Hit Rate score which was a fraction of 'Yes' responses to images in the first quartile over the total first quartile images. The numerator and denominator are offset by constants, a convention within the field for studies that do not exclude participants who choose a single response for all trials (e.g., only respond 'Yes').

Images that could be classified as false alarms were those in the third quartile, for which participants responded 'Yes' indicating they detected an object in an image where most participants did not (53 images with <23% recognition rate). False Alarm Rate was calculated based on the number of third quartile stimuli that participants endorsed as containing known objects:

$$FAR = \frac{False\ Alarms + 0.5}{False\ Alarms + Correct\ Rejections + 1}$$

where correct rejections were images in the third quartile to which participants responded 'No' as expected. The final d' score was calculated as:

$$d' = Z(Hit\ Rate) - Z(False\ Alarm\ Rate)$$

Fragmented Ambiguous Object Task (Version 2) EEG Administration: The EEG version of FAOT was completed as part of a separate visit in which a larger EEG session was completed in the Dr. Sponheim's EEG recording suite at the Minneapolis VA. In the EEG variation of the task, participants saw the same images as those in the Version 2 behavioral task. Participants viewed all 217 images in random order during continuous EEG data collection. Participants judged whether each image contained a "short and fat" or "tall and skinny" object, as quickly as possible. The tall and short conditions were counter-balanced to allow for analysis to ensure results are not driven by contour shape. Participants initially saw fixation screen in each trial; the timing was jittered randomly from 2000 to 2700ms. Participants then viewed each image for 1000 ms followed by a fixation dot screen for up to 7000ms to allow for a response and prevent trial overlap in analysis. The fixation dot appears on all screens to avoid neural response to the fixation appearing and disappearing. EEG task duration is approximately 10 minutes. Images were presented in random order in an event-related design. The task was programmed in PsychoPy2 and viewed on a PC computer in the EEG laboratory from a distance of 133 cm to maintain a subtense of 4.5 degrees. The 217 image version of the task is also completed in fMRI during a subsequent visit as part of Dr. Sponheim's larger grant, allowing for behavioral test-retest reliability calculations across methodologies in future analyses.

Visual Acuity: All participants completed visual acuity measures at a distance of one meter during the EEG session described in Study 3. Performance was quantified by log of the Minimum Angle of Resolution (LogMAR) units, with higher values signifying poorer acuity. Measurements were made using any corrective lenses participants wore during the visit.

Questionnaires: Participants completed the Multidimensional Personality Questionnaire (MPQ) Absorption subscale and the full Personality Inventory for DSM-5 (PID-5). As in Study 1, the 34 Absorption items were administered interspersed in the PID-5 questionnaire. Two effort questions were also included in the questionnaire to assure that participants were comprehending and appropriately responding to questions.

Neuropsychological Measures: Full-scale Intelligence quotient (IQ) was estimated using the Block Design and Vocabulary subtests (Brooker & Cyr, 1986) of the Wechsler Adult Intelligence Scale, Third Edition (WAIS-III; Wechsler, 1997) administered by trained research staff.

Electroencephalography (EEG) Procedures

EEG recordings were made with a BrainVision actiCHamp EEG system. The recording cap contained 128 active electrode channels conforming to the Unified Optimized Layout based on the 10–20 International System (Chatrian et al., 1988).

Impedances were less than 100 kΩ for all participants and electrode sites before impedance transformation by the active electrodes. Continuous data was collected at 1000 Hz sampling rate referenced to Cz. Vertical and horizontal electro-occulograms (VEOG and HEOG) were monitored by electrodes placed above and below the right eye and on the left and right temples, respectively. After completion of recording, data was imported to Matlab (Mathworks, Inc.) for offline processing. Data was downsampled to 256Hz and re-referenced to the scalp average. A bandpass filter of 0.5Hz to 256 Hz was applied when files were imported into Matlab for preprocessing.

Filtering, artifact rejection and correction, and spherical spline interpolation for bad electrodes were carried out through a semi-automated Matlab toolbox, ICAcleanEEGv1.3 (Kang et al., 2015). The toolbox is a methodological strength of the study. The toolbox uses independent components analysis (ICA) to isolate physiological and electrical artifact components, such as eye-movements, electrocardiogram, muscle movements, and 60Hz environmental noise. Artifacts are categorized empirically, based on regression parameters of large EEG datasets. ICA ocular correction minimizes deletion of data and distortion of the EEG signal (Vigário, 1997). Ocular artifacts are corrected rather than deleted, which maximizes included trials for patients who have greater blink rates[41]. The user has the flexibility to override automated suggestions if needed; these decisions are based on concrete preprocessing guidelines and made by group consensus by the EEG technicians. Data were epoched and mean baseline corrected for each trial from 500ms pre-stimulus to 1500ms post-stimulus. Baseline correction was applied as the mean amplitude of the 200 ms to 0 ms pre-stimulus period for individual trials. Epoched data underwent a lowpass Butterworth filter with a half-amplitude cutoff of 30Hz then single trial mean ERPs were calculated. Original and preprocessed signal was visually inspected to ensure consistency and report the number of removed independent components.

Components were calculated as mean amplitude across a cluster of adjacent electrodes. P1 was considered at electrodes P5/P3/P4/P6 at 80-140ms. Past studies have quantified N1 using a range of occipital, parietal, and parieto-occipital electrodes. In the current study, N1 was maximal at occipital sites O1/Oz/O2 at 100-200ms; a less pronounced component was visible at parieto-occipital electrodes during the same time window so the occipital sites were used. N_{CL} was considered at electrodes PO7/PO3/PO4/PO8 at 270-320ms. A frontal component was measured at electrodes F1/Fz/F2 between 130-210ms and 250-400ms. Two time windows were investigated because both showed prominent ERPs and a central goal of the research was to better understanding the timing of top-down processes during object recognition. One additional electrode, a negative deflection consistent with the N400 component, was identified through post-hoc visual observation and included at electrodes C1/Cz/C2 between 250-400ms. The signal was internally consistent between the sites including in each component cluster (Cronbach's α: 0.85-0.99) implying that each site cluster captured a common signal.

Statistical Analysis

The current study aimed to isolate the relationship between object detection ability, timing of scalp activation, and abnormal perceptual experiences. Furthermore, the proposed analyses allow comparison between traditional dichotomous diagnoses and a continuous personality trait of apophenia. A series of multilevel models were constructed to test the three aims. All analyses correct for age, gender, visual acuity, WAIS estimated full-scale IQ and medication effects. When modeling the Openness/Intellect trait of the Five Factor Model of normative personality, Absorption falls on the Openness end of the simplex while IQ falls on the side of Intellect. The Openness and Intellect ends of the simplex show a weak, negative correlation. Thus, including IQ as a covariate was particularly important to Aim 3 because it may better isolate the variance of Absorption (DeYoung et al., 2012). Chlorpromazine equivalents were included as a covariate to ensure that antipsychotic dosage medication was not driving the observed effects.

As well, I considered the need to test for effects of family membership. Oftentimes the patient and relative groups contain individuals from the same family. Before performing the multilevel models, chi-square tests of independence were carried out on all ERP variables, object detection performance measures, and trait measures to ensure the assumption of independence was not violated by family membership. Past studies in Dr. Sponheim's lab have shown minimal to no contribution from family clusters (Silberschmidt & Sponheim, 2008). Likewise, none of the variables in the current sample violated independence and family membership was not included as a random effect. Lastly, VIF and tolerance levels were inspected in each analysis to protect against effects of multicollinearity. All analyses showed acceptable levels of VIF (< 5) and tolerance (> 0.2).

The first set of regression analyses addressed the first aim by testing group differences in object detection. Object detection, quantified as FAOT Proportion 'Yes', was the dependent variable. Age, gender, visual acuity, WAIS IQ and chlorpromazine equivalents were entered into the first step of the regression to see if the covariates accounted for FAOT performance. The second step of the regression addressed the main hypothesis of the first aim. Participant group was added as a predictor. Healthy controls, first-degree relatives of patients with bipolar disorder, first-degree relatives of persons with schizophrenia, persons with bipolar disorder, and patients with schizophrenia formed five group categories. Group was then replaced by MPQ Absorption in all models, to see if the trait might be a stronger predictor of FAOT scores.

The second set of analyses tested hypotheses specific to ERP findings. A set of regressions compared the relationship between ERPs and participants group to the relationship between ERPs and the personality trait MPQ Absorption. A hierarchical regression was carried out for each of the components identified during EEG processing – P1, N1, N_{CL}, two frontal components and N400 – for a total of six separate statistical models to test group differences in scalp response. The first step included the covariates: age, gender, visual acuity, WAIS IQ and chlorpromazine equivalents. The second step added the group variable. The analyses were repeated, replacing MPQ Absorption for the group variable.

Subsequently, a set of regression analyses tested whether performance on the behavioral FAOT task during the clinical visit predicted ERPs during the EEG task. As with all other analyses, covariate predictors were entered in the first step of the model.

FAOT Proportion 'Yes' was added at the second step. A separate model was run with each ERP as the dependent variable. Since there were six separate hypotheses for each step of this aim, the results were corrected for multiple comparisons using the Šidák correction (α = 0.008; Šidák, 1967).

Power Analysis

When proposing the current analyses, we carried out power analysis to ensure that the sample was sufficient to answer the research questions. For the first aim, a power analysis was carried out based on findings of lowered object detection performance in patients with schizophrenia as compared to controls (η^2_p =0.23; Butler et al., 2013). At a power level of 0.8, a total sample of 39 subjects would be sufficient to detect the observed small effect size in a fixed effect, omnibus, one-way ANOVA. Our proposed sample size surpasses the sample estimated to reach power of 0.95.

Previous studies report small to medium effect sizes for P1 and N_{CL} amplitude differences between patients with schizophrenia and controls. At the observed small effect sizes (effect size f = 0.60), 36 participants would be sufficient to detect P1 differences at 0.8 power across three groups in a fixed effect, omnibus, one-way ANOVA. A total of 36 participants is estimated to reach 0.8 power to detect differences in N_{CL} across three groups (effect size f = 0.54). Due to a lack of published descriptive statistics and effect sizes, power could not be calculated for the frontal components. However, the P1 and N_{CL} estimates indicate that the proposed sample size of 150 is sufficient for detecting group differences of small effect sizes with sufficient power.

For the third aim, a sensitivity analysis was carried out based on the pilot study results showing that Absorption scores predicted Fragmented Ambiguous Object Task recognition rates in an undergraduate sample (R^2=0.07). At a power of 0.8, 102 total subjects would be sufficient to reach significance in a two-tailed linear bivariate regression. The comparison between Absorption and ERPs is novel and has no data by which to directly estimate the sample needed for sufficient power. However, based on the other power analyses carried out for this proposal the proposed sample size of 150 participants is expected to detect small effect sizes at a power level of 0.8 or above.

Results

FAOT Behavioral Task

Study 2 extended the aims of Study 1 into a clinical sample. Object detection patterns were explored across individuals with psychotic spectrum disorders, first-degree relatives, and psychiatrically unaffected controls. There were two arms to the approach. First, object detection performance was examined across traditional diagnostic categories in a between-groups analysis. Second, the hypothesis that the individual differences approach taken in Study 1 would better explain variation in object detection was tested. The association between trait measures of apophenia – MPQ Absorption and PID-5 Psychoticism – and task performance was expected to be positive, reflecting a tendency for people with high apophenia to more readily perceive patterns. Age, gender, chlorpromazine equivalent, visual acuity, and IQ were included as covariates in both models.

One hundred sixty-nine participants completed the behavioral version of the

***Table 7. Characteristics of Study 2 Clinical Sample**. Study 2 (N=141) included participants with serious mental illness related to psychosis, first-degree relatives, and psychiatric controls. Overall statistics are reported for demographic, cognitive, vision, clinical, and behavioral performance variables, with superscripts denoting post-hoc group comparisons. IQ, visual acuity, and current symptom measures were largely similar amongst controls and relatives, and deviated from baseline in the patient groups.*

	CON	REL-BP	REL-SZ	BP	SZ	Statistic
N (% Male)	28 (43%)	18 (56%)	24 (33%)	34 (59%)	37 (65%)	$\chi^2 = 7.46$
Age	46.39 (9.88)	42.22 (11.93)	47.75 (8.64)	46.71 (10.44)	45.03 (10.02)	$F_{4,136}$= 0.93
Estimated IQ	112.07 (13.32)[e]	108.33 (16.36)	104.38 (13.93)	103.15 (14.4)	98.76 (13.52)[a]	$F_{4,136}$= 3.93*
Visual Acuity	0.07 (0.12)	0.02 (0.06)[de]	0.06 (0.09)	0.11 (0.14)[b]	0.11 (0.13)[b]	$F_{4,136}$= 2.85*
<u>BPRS</u>						
Positive	5.00 (0.00)[de]	5.83 (2.81)[e]	5.17 (0.48)[e]	5.94 (1.63)[ae]	9.76 (5.3)[abcd]	$F_{4,136}$= 14.14*
Negative	3.21 (0.69)[e]	3.83 (1.58)	3.38 (1.17)	3.85 (1.42)	4.27 (2.1)[a]	$F_{4,136}$= 2.39†
Disorganization	4.46 (0.88)[cde]	5.89 (1.94)[e]	5.88 (2.05)[ae]	6.94 (2.17)[a]	7.95 (2.94)[abc]	$F_{4,136}$= 11.24*
Depression	3.71 (1.44)[cde]	5.28 (2.05)	5.46 (2.55)[a]	6.82 (4.23)[a]	6.59 (3.35)[a]	$F_{4,136}$= 5.02*
Mania	3.46 (1.2)	3.89 (1.53)	3.33 (0.7)[e]	4.47 (2.67)	4.28 (1.64)[c]	$F_{4,136}$= 2.35†
<u>FAOT</u>						
Yes (%)	37.95 (16.38)	43.41 (15.04)	42.98 (24.9)	46.95 (21.76)	37.22 (16.73)	$F_{4,136}$= 1.57
d'	2.32 (0.89)	1.86 (1.54)	1.51 (1.2)	1.75 (0.87)	1.59 (1.13)	$F_{4,136}$= 2.56†

<u>Note.</u> One participant is missing a visual acuity measure. Visual acuity is reported in log of the Minimum Angle of Resolution (LogMAR) units, with higher values signifying poorer acuity; measurements were made wearing any corrective lenses used during the visit. Intelligence quotient (IQ) was estimated from WAIS-IV Block Design and Vocabulary Subtests. BPRS is the Brief Psychiatric Rating Scale.

† threshold of significance ($0.05 \leq p < 0.1$); *$p<0.05$; Post-hoc group comparisons: a= differed from healthy controls; b= differed from relatives of persons with bipolar; c= differed from relatives of persons with schizophrenia; d= differed from persons with bipolar; e= differed from persons with schizophrenia.

FAOT task. Sixteen participants were removed from analyses because they responded to less than 75% of trials, or exclusively responded with one response key (i.e., only pressed

‘No’ or only pressed ‘Yes’). A further 18 participants were missing MPQ Absorption scores. Thus, 135 participants had good quality data available for analyses that included Absorption and FAOT behavioral results. For PID-5 analyses, 12 participants were missing questionnaire data, leaving 141 participants with PID-5 and FAOT data.

Table 8. Group Membership as a Predictor of FAOT Performance in Multiple Regression Analysis. *FAOT behavioral performance was similar amongst controls, relatives, and persons with psychotic disorders. Visual acuity was the strongest predictor of FAOT performance.*

	β	b	SE	t	95% CI	p-value	
Step 1							
Intercept		*0.35*	*0.052*	*6.71*	*[0.245, 0.45]*	*0.000*	
Age	-0.13	-0.03	0.017	-1.53	[-0.06, 0.008]	0.129	
Gender	0.12	0.04	0.034	1.33	[-0.022, 0.111]	0.187	
Chlorpromazine Equivalent	-0.02	0.00	0.016	-0.28	[-0.035, 0.027]	0.782	
Visual Acuity	-0.19	-0.04	0.017	-2.16	[-0.071, -0.003]	0.033	*
Full Scale IQ	-0.15	-0.03	0.016	-1.74	[-0.061, 0.004]	0.084	†
Step 2							
Intercept		*0.31*	*0.071*	*4.33*	*[0.168, 0.449]*	*0.000*	
Age	-0.13	-0.03	0.017	-1.48	[-0.06, 0.009]	0.142	
Gender	0.13	0.05	0.034	1.42	[-0.019, 0.115]	0.158	
Chlorpromazine Equivalent	-0.04	-0.01	0.016	-0.46	[-0.039, 0.024]	0.647	
Visual Acuity	-0.21	-0.04	0.018	-2.28	[-0.075, -0.005]	0.024	*
Full Scale IQ	-0.13	-0.02	0.017	-1.41	[-0.058, 0.01]	0.163	
Group	0.08	0.01	0.013	0.80	[-0.015, 0.036]	0.425	

Note. One participant is missing a visual acuity measure. Visual acuity is reported in log of the Minimum Angle of Resolution (LogMAR) units, with higher values signifying poorer acuity; measurements were made wearing any corrective lenses used during the visit. Intelligence quotient (I was estimated from WAIS-IV Block Design and Vocabulary Subtests. BPRS is the Brief Psychiatric Rating Scale.

† threshold of significance ($0.05 \leq p < 0.1$); * significant ($p < 0.05$)

The sample characteristics were comparable in both subsets. As shown in Table 7, age and gender were equivalent across the samples. However, persons with schizophrenia had the lowest intelligence. Both patient groups had poorer visual acuity than relatives of bipolar participants. On average, participants vision was between 20/20 and 20/25 in

Snellen values (LogMAR mean = 0.08, SD = 0.12). Of the five BPRS symptom factors. Positive, disorganized, and depression symptoms showed significant group differences. The symptom profiles match the diagnostic criterion for each group. The schizophrenia group had the highest levels of positive and disorganized symptoms. The bipolar group had the highest average of depression and mania. The two relative groups had symptom levels in between the control and patient groups in almost all symptom domains.

In testing the hypotheses, the first step of each model included the covariates as the only predictors and accounted for a small portion of the variance in FAOT responses (R^2_{adj} = .043, $F(5, 128)=2.20$, $p=.059$). Visual acuity was the strongest predictor ($\beta= -0.19$, $p<0.05$); participants with better vision saw a known object in more trials. IQ was at the threshold of significance ($\beta= -0.15$, $p=0.08$) with lower intelligence associated with higher object detection. Adding the group variable in the second step did not improve the model ($\Delta R^2= 0.005$, $\Delta F(6, 127)=0.64$, $p=0.43$; see Table 8). Thus, the findings suggested that group was not a suitable predictor of object detection; participant groups did not differ in task performance, as measured by proportion of FAOT 'yes' responses. Across the entire sample, participants detected objects an average of 41% of trials (SD=19%). The lack of a group difference is somewhat surprising given that past studies have found large behavioral deviations in clinical populations. The results suggest that persons with mental illness detect as many meaningful representations in visual stimuli as healthy persons, and have comparable response rates when explicit identification of the objects is required.

Table 9. MPQ Absorption as a Predictor of FAOT Performance in Multiple Regression Analysis. *Better visual acuity (scores closer to 0) predicted higher object detection.*

	β	b	SE	t	95% CI	p-value
Step 1						
Intercept		*0.35*	*0.052*	*6.71*	*[0.245, 0.45]*	*0.000*
Age	-0.13	-0.03	0.017	-1.53	[-0.06, 0.008]	0.129
Gender	0.12	0.04	0.034	1.33	[-0.022, 0.111]	0.187
Chlorpromazine Equivalent	-0.02	0.00	0.016	-0.28	[-0.035, 0.027]	0.782
Visual Acuity	-0.19	-0.04	0.017	-2.16	[-0.071, -0.003]	0.033 *
Full Scale IQ	-0.15	-0.03	0.016	-1.74	[-0.061, 0.004]	0.084 †
Step 2						
Intercept		*0.35*	*0.052*	*6.62*	*[0.242, 0.449]*	*0.000*
Age	-0.14	-0.03	0.017	-1.56	[-0.061, 0.007]	0.121
Gender	0.12	0.05	0.034	1.36	[-0.021, 0.113]	0.175
Chlorpromazine Equivalent	-0.03	-0.01	0.016	-0.31	[-0.036, 0.026]	0.758
Visual Acuity	-0.19	-0.04	0.017	-2.15	[-0.071, -0.003]	0.033 *
Full Scale IQ	-0.15	-0.03	0.016	-1.71	[-0.06, 0.004]	0.090 †
MPQ Absorption	0.04	0.01	0.017	0.47	[-0.025, 0.041]	0.636

Note. Visual acuity is reported in log of the Minimum Angle of Resolution (LogMAR) units; measurements were made wearing any corrective lenses used during the visit; one participant is missing a visual acuity measure. Intelligence quotient (IQ) was estimated from WAIS-IV Block Design and Vocabulary Subtests. BPRS is the Brief Psychiatric Rating Scale.

† threshold of significance ($0.05 \leq p < 0.1$); * significant ($p < 0.05$)

The main hypothesis was that personality traits of apophenia would be superior to group membership in predicting object detection performance. In contrast to the study hypothesis, neither personality trait was significantly correlated with FAOT performance. MPQ Absorption was not significantly correlated with performance (β= 0.04, p=0.64; see Table 9) and did not improve the model beyond the covariates (ΔR^2= 0.002, $\Delta F(6, 127)$=0.23, p=0.64). Likewise, PID-5 Psychoticism was not significantly associated with FAOT 'yes' responses (β= -0.02; ΔR^2= 0.002, $\Delta F(6, 133)$=0.07, p=0.79). Neither the normative nor the maladaptive measure of apophenia showed a meaningful association with object detection in the current sample of persons who were clinically affected or at familial liability for a psychotic spectrum disorder. The results were in opposition to past findings in the normative population. The findings were not explained by the effect of covariates; the correlation relationship between apophenia traits and object detection was consistently weak (Absorption: $r = 0.02$, $p=0.81$; Psychoticism: $r = -0.04$, $p=0.68$).

To investigate whether the null results were due to response bias, d-prime (d’) scores were calculated. This was somewhat exploratory since image recognition rates could not be validated in an independent sample. Categorization of trials was based upon the typical response patterns within the current, clinical sample. A “hit” was a yes response to the most commonly detected objects, images in the top quartile of recognition rates. First, d’ was considered with respect to visual acuity, the only predictor that was significantly associated with the proportion of FAOT yes responses. Upon further investigation at a more fine-grained level, visual acuity was most strongly (negatively) correlated with items that had greatest ease of recognition ($r = -0.24$, $p<0.01$). That is to say that those with worse vision were less likely to detect objects in the most easily recognizable trials. Next, the main hypothesis was investigated using d’. FAOT d’ was not significantly predicted by MPQ Absorption as compared to the first step that included the covariates ($\beta= 0.13$; $\Delta R^2= 0.084$, $\Delta F(6, 127)=2.25$, $p=0.14$). However, the association was far stronger than when using FAOT proportion yes metric. Absorption showed weak, but opposing correlations with Hit Rate ($r = 0.09$, $p = 0.29$) and False Alarm Rate ($r = -0.07$, $p = 0.41$). While these analyses do not allow rejection of the null hypothesis, they do suggest that Absorption does not lead to indiscriminately affirmative responses.

Rather, Absorption appears uniquely associated with findings patterns in stimuli that are conventionally meaningful.

Table 10. ***PID-5 Domain Traits as Predictors of FAOT Performance in Multiple Regression Analysis****. Higher Antagonism correlated with greater sensitivity to FAOT objects.*

	β	b	SE	t	95% CI	p-value
Step 1						
Intercept		*0.35*	*0.051*	*6.71*	*[0.243, 0.446]*	*0.000*
Age	-0.12	-0.02	0.017	-1.38	[-0.057, 0.001]	0.170
Gender	0.13	0.05	0.033	1.49	[-0.016, 0.115]	0.138
Chlorpromazine Equivalent	-0.03	-0.01	0.016	-0.32	[-0.036, 0.026]	0.751
Visual Acuity	-0.17	-0.03	0.017	-1.96	[-0.067, 0.000]	0.052 †
Full Scale IQ	-0.15	-0.03	0.016	-1.80	[-0.061, 0.003]	0.074 †
Step 2						
Intercept		*0.34*	*0.054*	*6.22*	*[0.230, 0.445]*	*0.000*
Age	-0.16	-0.03	0.017	-1.81	[-0.066, 0.003]	0.073
Gender	0.14	0.05	0.035	1.54	[-0.015, 0.124]	0.126
Chlorpromazine Equivalent	-0.01	0.00	0.017	-0.12	[-0.035, 0.031]	0.906
Visual Acuity	-0.13	-0.02	0.018	-1.36	[-0.060, 0.011]	0.177
Full Scale IQ	-0.18	-0.03	0.017	-1.96	[-0.068, 0.000]	0.052 †
Negative Affect	0.02	0.01	0.027	0.18	[-0.048, 0.058]	0.861
Detachment	-0.04	-0.01	0.028	-0.30	[-0.063, 0.047]	0.768
Antagonism	0.27	0.05	0.025	2.10	[0.003, 0.100]	0.038 *
Disinhibition	-0.14	-0.03	0.021	-1.31	[-0.069, 0.014]	0.191
Psychoticism	-0.12	-0.02	0.031	-0.74	[-0.085, 0.039]	0.459

Note. One participant is missing a visual acuity measure. Visual acuity is reported in log of the Minimum Angle of Resolution (LogMAR) units, with higher values signifying poorer acuity; measurements were made wearing any corrective lenses used during the visit. Intelligence quotient (IQ) was estimated from WAIS-IV Block Design and Vocabulary Subtests. BPRS is the Brief Psychiatric Rating Scale.
† threshold of significance ($0.05 \leq p < 0.1$); * significant ($p < 0.05$)

Given the null results, a final post-hoc analysis was carried out on the five domain traits in the PID-5 to see whether variance unique to one of the factors might better account for task performance. A regression included all covariates and the five domains as predictors and FAOT proportion ‘yes’ as the dependent variable. The model accounted for a small degree of FAOT performance ($R^2_{adj} = .04$; see Table 10). The one significant predictor was Antagonism, which was positively associated with FAOT scores ($\beta = 0.27$, $p<0.05$, 95% CI [0.003, 0.100]). Though most of the domains did not reach significance, it is worth noting that the three domains with the largest coefficient values were the same as those in the Study 1 undergraduate sample. However, the direction of the association with FAOT endorsements was in the opposite polarity. Antagonism was negatively associated with FAOT scores in the undergraduate sample, but is positive in the current clinical sample ($\beta = 0.27$). Disinhibition and Psychoticism were positive in Study 1 and are negative in the current study (Disinhibition: $\beta = -0.14$; Psychoticism: $\beta = -0.12$).

FAOT Electroencephalography Task

The second portion of Study 2 investigated ERPs during object detection with the goals of replicating and clarifying the timing of frontal components observed in the object detection literature, and investigating whether group membership or apophenia traits better account for variations in ERP amplitudes. Five ERPs (P1, N1, N_{CL}, $P1^F$, N^F_{CL}) were defined a priori based on the object detection literature. A sixth component, N400, was identified through visual observation of the waveforms and included in analysis. N400 is classically produced when individuals see a word that is semantically or grammatically incongruent with the context, but can also be elicited by semantic processing of non-verbal stimuli (Kutas & Federmeier, 2011). Of the candidate ERPs, the amplitudes of anterior components were hypothesized to be maximal in patients and relatives, due to greater reliance on prior knowledge and shared genetic liability for abnormalities in long-range feedback from frontal regions. Absorption was expected to be associated with attenuation of P1 and N_{CL}, the two components that are commonly modulated in persons with schizophrenia during object detection.

One hundred thirty-four participants had data from the behavioral FAOT task and good quality FAOT EEG recordings (CON=25, REL-BP=19, REL-SZ= 22, BP=33, SCZ=35). Of this subsample, one hundred twenty-one participants had also completed MPQ Absorption questionnaire. The subsample was largely comparable to participants described in the FAOT behavioral analysis. Group differences were again apparent in IQ ($F(4,129)= 4.14$, $p<0.05$) and BPRS Positive ($F(4,129)= 13.34$, $p<0.05$), Depression ($F(4,129)= 4.54$, $p<0.05$), and Disorganization ($F(4,129)= 8.89$, $p<0.05$) factors. The group difference in BPRS Mania reached significance; the bipolar group had slightly higher levels of mania than in the behavioral sample. Visual acuity was at the threshold of significance ($F(4,129)= 2.43$, $p=0.05$).

Previous electrophysiological research of object detection tasks identified two potential frontal components, one temporally overlapping P1 and one temporally overlapping the negative closure component (N_{CL}). Prominent positive deflections consistent with both components were apparent across the frontal electrodes of interest bilaterally (F1, Fz, F2). Thus, an early (130-210ms) and later (250-400ms) frontal component, termed $P1^F$ and N^F_{CL} respectively, were included in analyses. In an analysis of all ERPs, there was no difference between tall versus short trials ($F(4,129)= 0.05$, $p=0.82$).

The main effect of group was tested in a series of six two-step regression analyses. The first step included the covariates age, gender, chlorpromazine equivalents, visual acuity, and IQ. The second step added the group variable. After controlling for covariates, group differences not observed in P1 (β= -0.09, p=0.33; ΔR^2= 0.01, $\Delta F(6, 127)$= 0.97), N1 (β= 0.02, p=0.87; ΔR^2= 0.00, $\Delta F(6, 127)$= 0.03), N_{CL} (β= -0.04, p=0.64; ΔR^2= 0.002, $\Delta F(6, 127)$= 0.22), $P1^F$(β= 0.01, p=0.96; ΔR^2= 0.00, $\Delta F(6, 127)$= 0.003), or N^F_{CL} (β= 0.07, p=0.44; ΔR^2= 0.004, $\Delta F(6, 127)$= 0.61). N400 was predicted by group membership (β= 0.26, p<0.01) above and beyond the covariates (ΔR^2= 0.05, $\Delta F(6, 127)$= 7.48, p< 0.01). None of the covariates were significantly associated with N400 amplitude. The full model predicted a small portion of N400 mean amplitude variance (R^2_{adj} = .09). As seen in Figure 4, N400 was attenuated in the patient groups as compared to controls and relatives. The hypothesis that group differences would be observed in P1, negative closure, and frontal components was not supported (see Appendix A for waveforms and topography of all components). The role N400 plays in semantic processing has implications for high-level feedback during implicit detection of degraded object stimuli.

Next, Absorption was substituted for group in the analyses to see if it might be more closely related to electrophysiological activity during the task. Absorption was not significantly correlated with mean amplitude of any of the ERP components: P1 (β= -0.005, p=0.96; ΔR^2= 0.00, $\Delta F(6, 114)$= 0.003); N1 (β= 0.04, p=0.63; ΔR^2= 0.002, $\Delta F(6, 114)$= 0.23); N_{CL} (β= -0.01, p=0.92; ΔR^2= 0.000, $\Delta F(6, 114)$= 0.01); $P1^F$(β= 0.06, p=0.54; ΔR^2= 0.003, $\Delta F(6, 114)$= 0.37); N^F_{CL} (β= 0.02, p=0.79; ΔR^2= 0.001, $\Delta F(6, 114)$= 0.07); N400 (β= 0.09, p=0.33; ΔR^2= 0.008, $\Delta F(6, 114)$= 0.96). Given the weak correlations between behavioral performance and Absorption, it is reasonable that there would not be a strong relationship between the trait measure and brain-based variables. The effects of

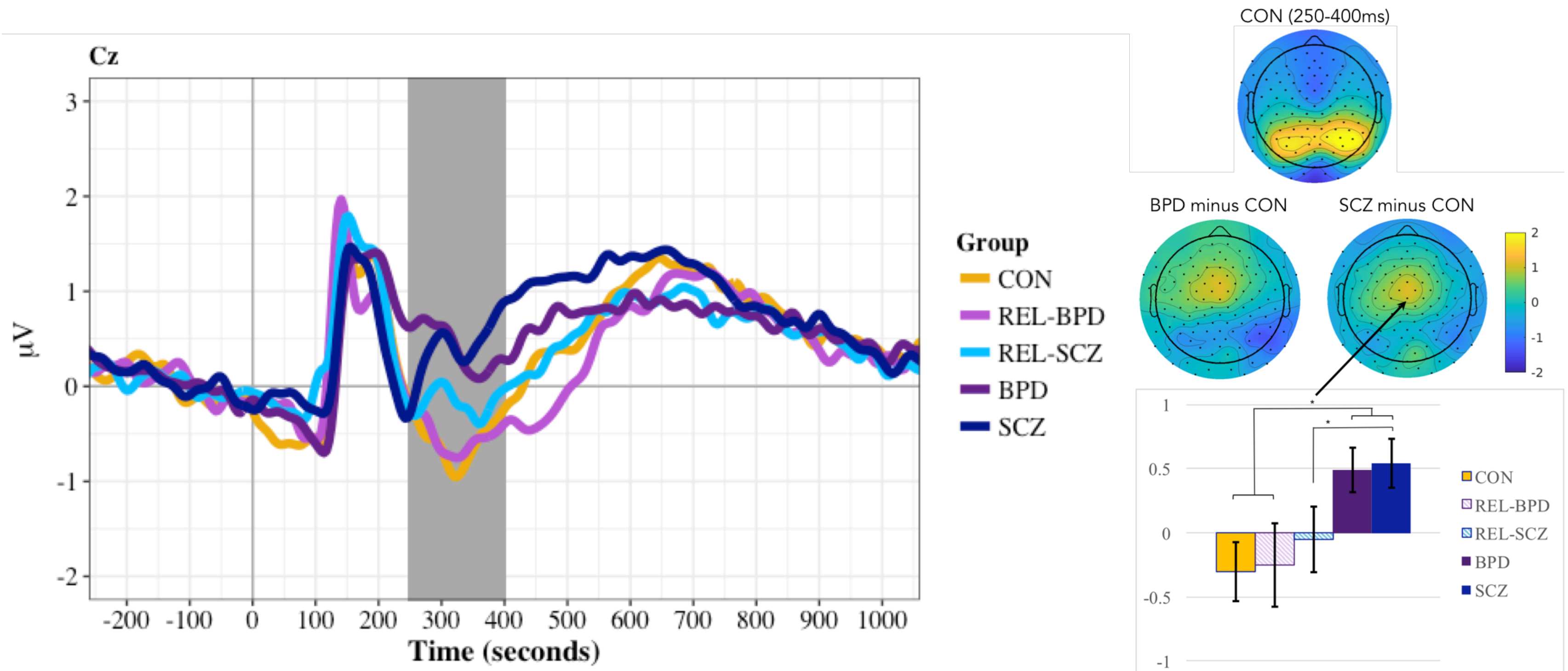

Figure 4. Group Differences in the N400 Component. *The N400 response, most often observed in situations of linguistic discordance, was attenuated in persons with schizophrenia or bipolar disorder. The group differences suggest that controls and relatives may be relying more heavily than patients on semantic processing when viewing stimuli. The varied semantic qualities of FAOT stimuli and well-controlled low-level visual stimuli may intensify higher-order cognition like semantic processing.* ***Left:*** *the N400 waveform is depicted at site Cz, with the time window of interest highlighted in gray.* ***Top right:*** *maps of the N400 scalp topography for control participants, and of the difference between controls and each patient group.* ***Bottom right:*** *mean amplitude values across all N400 sites (Cz, C1, C2) as used in the statistical models are shown in the bar graph; error bars are standard errors of each group.*

the personality trait appear unrelated to neural processes elicited by this particular paradigm.

The last set of analyses tested the relationship between the behavioral FAOT paradigm, in which participants explicitly indicated whether or not they saw an object in each stimulus, and ERP components during the EEG FAOT paradigm. The analysis that

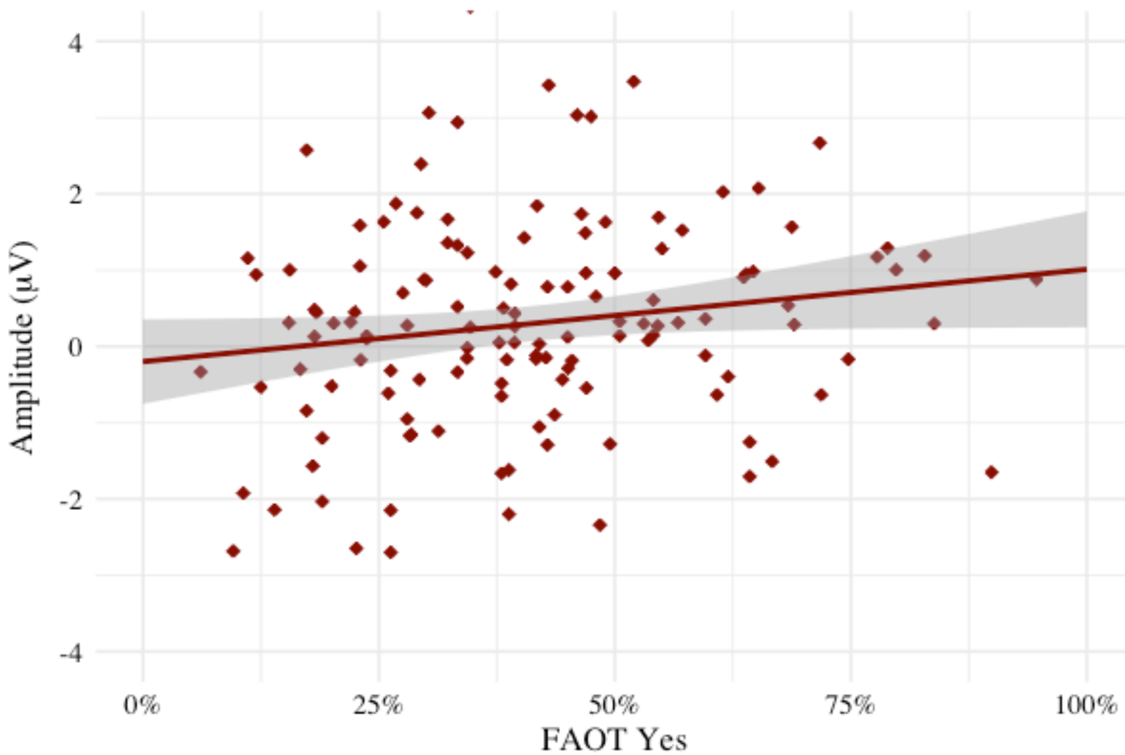

Figure 5. ***$N^F{}_{CL}$ as Predicted by FAOT Behavioral Performance.*** *The negative frontal closure ($N^F{}_{CL}$) component was attenuated (i.e., amplitude was more positive) for those who endorsed more images as objects on the previous, behavioral administration of FAOT.*

included $N^F{}_{CL}$ was the only model that survived corrections for multiple comparisons ($R^2_{adj} = .13$, $p<0.01$). Participants who endorsed a higher proportion of FAOT images as containing known objects had smaller $N^F{}_{CL}$ components ($\beta = 0.17$, $p<0.05$; see Figure 5).

However, age (β= 0.26, $p<0.01$) and gender (β= -0.21, $p<0.05$) were stronger predictors of N^F_{CL} than FAOT performance. Older individuals and men had smaller N^F_{CL} response. IQ was also at the threshold of significance (β= -0.17, p=0.051); higher IQ was associated with larger N^F_{CL}. Thus, participant characteristics and object endorsements during previous exposure to the object detection task predicted the later frontal component.

Discussion

Study 2 considered object detection from multiple levels of analysis and ultimately did not find associations with apophenia or psychosis. In contrast to study hypotheses and multiple previous studies, performance by participants with psychotic disorders did not differ from that of controls, and personality traits in the apophenia domain did not correlate with object detection. Furthermore, there were minimal between-group differences in ERPs during object detection. ERPs that have been linked to semantic processing and top-down processing were most closely related to traditional diagnostic category boundaries and FAOT performance.

In the first set of regression analyses, neither participant group nor personality traits significantly predicted the number of objects detected in the FAOT task. It was expected that the main effect of apophenia traits would be significant, and that intelligence would moderate the effect (i.e., there would be an interaction between Absorption and intelligence). Instead, Antagonism and visual acuity were stronger predictors than group, the normative MPQ Absorption trait, or the maladaptive PID-5 Psychoticism trait. Antagonism, the maladaptive range of Agreeableness, is characterized by high levels of manipulativeness, deceitfulness, and grandiosity. There is not a theoretical foundation linking Antagonism and object detection. The finding must be replicated in independent samples. I offer some cautious possibilities for the results. Those high in Antagonism are also more likely to reject social norms and believe their ideas are superior, making them more open to interpreting the world in a way that others do not. Alternatively, participants may have been rebellious and chosen to complete the task in an unconventional or inaccurate manner. In the latter case, I would not expect the finding to replicate in future studies.

The null results with respect to the central hypotheses of the first aim were not driven by the effects of covariates. The results were largely the same when covariates were removed from the models. In addition, bivariate correlations between traits and object detection were weak. Variations in visual acuity, even at levels that are not deemed impaired, appear to be an important predictor of object detection. Previous work has shown that detection of oval JOVI contours is similarly affected by visual acuity levels that are better than 20/20 (Keane, Kastner, Paterno, & Silverstein, 2015). This raises the question of whether visual perceptual abnormalities arise from physical or cognitive impairments. People with psychotic disorders have high incidence of visual problems with a physical basis, such as retinal abnormalities or undercorrected vision (Viertiö et al., 2007). Physical visual deficiencies bias the sensory input, regardless of subsequent cognitive processing. It is likely that visual acuity only explains a portion of visual disturbances in psychotic populations given that deficits are not observed across all paradigms or clinical samples.

The heterogeneity of clinical samples may also contribute to inconsistent findings in visual research. Clinical features such as chronicity, current and lifetime symptoms, and medication add variability that is not present in normative samples and may require larger sample sizes to reliability detect the hypothesized effect. The current study may simply have been underpowered. A minimum of around 200 participants is suggested for 80% power in studies with effect sizes around 0.2, the average effect size in personality research (Richard et al., 2003). Clinical features may also meaningfully contribute to visual abnormalities. Antipsychotic dosage, quantified by chlorpromazine equivalent, did not significantly predict FAOT performance or ERP amplitude in any of the models. Yet, the current sample is older and more chronic, which may modulate the presentation of sensory dysregulation and the underlying mechanisms. Additionally, participants undergo extensive clinical screening that includes structured clinical interviews for past and present DSM-IV-TR diagnoses, including personality disorders. The protocol procedures may lead to a more specialized sample.

The second set of analyses sought to clarify the timing of neural responses during object detection using EEG. In addition to three ERP components that are well-established in visual integration research, I confirmed the timing of two anterior components and observed the N400 component. P1, N1, N_{CL}, and the early anterior component were intact for all participants, suggesting that dorsal and ventral stream processing is preserved during FAOT object detection. However, both patient groups produced attenuated N400s, and the later anterior component (N^{F}_{CL}) correlated with FAOT behavioral performance.

The N400 component has not be incorporated into previous studies of object recognition so it was outside of the initial hypotheses. Nonetheless, the role of the N400 is consistent with the task manipulation. N400 indexes the degree of semantic processing of both linguistic and nonlinguistic stimuli like objects (Kutas & Federmeier, 2011). N400 is elicited when viewing pictures for which one has greater knowledge like familiar versus rare objects (Rahman & Sommer, 2008). FAOT was specifically designed using known, meaningful objects, and incorporates more semantically varied stimuli than many other visual integration tasks. The stimuli were hypothesized to rely more heavily on higher-order processing related to prior knowledge. The N400 is evidence that participants activated semantic networks when viewing the stimuli. Attenuated N400 in persons with schizophrenia, as observed in the current study, has been widely reported in the literature particularly during semantic priming paradigms (Minzenberg, Ober, & Vinogradav, 2002). In healthy populations, N400 is enlarged by priming, in semantic priming paradigms and when stimuli have been seen previously viewed. This introduces the idea that our research protocol design, which included multiple administrations of FAOT, may have produced the N400 and attenuated other ERP responses, particularly at parietal sites (Ko, Duda, Hussey, Mason, & Ally, 2014).

The N400 is elicited in memory tasks as an index of familiarity. The N400 is larger for stimuli that the participant vaguely has a sense they have seen before, even if they are not confident or able to explicitly remember the stimulus (Voss & Federmeier, 2011). The effects occur without instructions that stimuli are related (Swaab, Ledoux, Camblin, & Boudewyn, 2011). Thus, our participants may have experienced the EEG task stimuli as familiar after having previously completed the behavioral task. The N400 and a more anterior component, "FN400", may be part of a larger network that supports contextual modulation and recognition (Amoruso, Cardona, Melloni, Sedeño, & Ibanez, 2012). The contextual modulation theoretical model integrates the roles of N400 in semantic processing and familiarity. Individuals use prior knowledge, including semantic information, to identify a visual scene based on its surroundings. The model generalizes across modalities and to real-world functioning (Baez et al., 2013).

Contextual modulation may also explain why we observed concurrent anterior negativity. The anterior negative component, which we term N^{F}_{CL} based on its temporal proximity to the negative closure ERP, shares the spatial and temporal properties of FN400. Study 2 found smaller N^{F}_{CL} for participants who had detected more objects in the behavioral task. If familiarity effects were driving the component, I would expect N^{F}_{CL} to be larger for the object participants detected in the behavioral task, since a 'yes' response signifies some degree of conceptualization of the embedded object. Since this was not a memory task, there was no direct contrast of previously seen images against new images. Therefore, it is not possible to directly compare the N^{F}_{CL} and FN400. The overlap between these components deserves more attention in studies specifically designed to contrast semantic processing and familiarity effects.

The study hypothesized that anterior ERPs indexed the timing of feedback from higher-order neural processes. This explanation seems more likely with the pattern of N^{F}_{CL}. When they responded 'yes' to images in the behavioral task, participants would likely have matched images to known objects. Thus, orchestration of a match between sensory input and prior knowledge would not be needed for those images during EEG recording. At the least, it is reasonable to think frontal regions would be less relied upon for previously detected images if participants could access the existing match.

The final hypothesis for Study 2 was that personality traits of apophenia and psychosis-proneness would be associated with visual stream ERPs while intelligence would be associated with anterior ERPs. Personality traits were not associated with any of the electrophysiological variables. The neural underpinnings of the personality traits considered in this study are not well understood (Allen & DeYoung, 2017; Ettinger et al., 2015). A complex system of factors influences how personality plays out in an individual's life; interpersonal traits may not be the most appropriate measure. The current conclusion is that the traits are either not related to the neurobiology of object detection or not the unit of analysis related to the electrophysiological demands of the task.

A variety of limitations may have led to the limited findings of Study 2 and could be addressed with future research. There is the possibility that EEG is not the best tool for investigating brain-based differences in object recognition when basic visual properties are controlled for. Magnetic resonance imaging (MRI) appears to have more consistent findings within the contour integration and perceptual closure literature. Alternatively, past findings may be largely influenced by the uncontrolled low-level visual properties of the stimuli (e.g., fluctuations in contrast or target size), and explicit naming of objects by participants. The results highlight limitations of the current approach and are informative for optimizing FAOT for EEG. First, the EEG task instructions could be modified to explicitly indicate whether or not they detect an object, identical to the behavioral task. This would assess the influence of explicit versus implicit detection and allow for ERP difference waveforms: ‘yes’ minus ‘no’ responses. It would also remove the need for multiple administrations of the task that I suspect induced priming effects. Second, I could define distinct trial conditions. I could add a random trial condition in which the element orientations are entirely random and do not contain an object. This would better account for baseline differences within-subjects because random trials could be subtracted from object trials for each participant. I also could use the current findings to establish a set of frequently detected and a set of infrequently detected objects to directly contrast in an independent sample (see Appendix B for supplementary analyses that suggest categorizing the EEG trials according to frequent vs. infrequent detection does not isolate a condition effect). Third, a suite of perceptual organization paradigms (for example: https://psytests.be/clinicians/test-centrum/l-post.php; Vancleef et al., 2015) would allow me to isolate mechanisms that are affected by psychotic disorders and related traits. Fourth, psychophysiological markers of object detection may reside in select frequencies. ERPs are phase-locked signals that may span a broad bandwidth. A time-frequency analysis could investigate frequency specific patterns in primate and human physiological research of visual integration. Furthermore, time-frequency analysis may be able to isolate feedforward communication, in the gamma band, and feedback communication, in the alpha and beta bands (Bastos et al., 2015; Markov et al., 2014; Michalareas et al., 2016).

Chapter 4: General Discussion

The current studies demonstrate a promising new research direction connecting apophenia to visual perception. Personality traits at the extreme end of Openness and psychosis-proneness clearly predicted amplified object detection in a normative sample (Study 1). Multiple measures of apophenia have now been associated with visual tasks across multiple normative and high-risk samples. Items on trait measures include all five senses, raising the possibility that visual perceptual effects reflect a broader phenomenon that spans multiple sensory modalities. According to contextual modulation theories, the contextual bias that influences sensory input and perceptual grouping likely influences other senses (Maróthi & Kéri, 2018). Planned analysis in the Study 1 sample will investigate how pattern detection in auditory and linguistic tasks relates to apophenia and intelligence.

The results also highlight the challenges of connecting research of normative and at-risk participants to that of clinical populations. The Study 1 findings did not replicate in a clinical sample (Study 2). The ERP results were not tied to personality; select components related to semantic processing and long-range feedback were related to group differences and object detection performance. Understanding psychosis through a personality lens is an ongoing research endeavor that has yet to reach consensus.

Our findings underscore the inconsistencies in determining whether Openness and psychotic traits form a continuous dimension. Psychoticism and Absorption were similarly correlated within Study 1 and Study 2, but the relationship with the dependent variable shifted. Adding a more conventionally normative Openness measure to Study 2 procedures would give us more information about how traits across the Openness domain relate to visual abilities. In Study 1, the correlation between Openness and Absorption was less strong than that of Psychoticism and Absorption, suggesting there is a large portion of the domain that is not represented by the individual instruments chosen for the studies. Representing the entire Openness dimension in future studies could explore if relationship between visual perception and traits is linear. The disconnect between the results of Study 1 and Study 2 suggests that the relationship shifts, particularly at the extreme edge of the domain. It is premature to conclude that traits are not valuable to perceptual research in clinical samples. Group explained as little variance as traits in Study 2. High within-group variability in clinical presentation and perceptual task performance suggest that diagnostic categories do not parsimoniously account for visual anomalies (Kessler et al., 2005; Krug, Brunskill, Scarna, Goodwin, & Parker, 2008). Further study is needed to understand how findings in healthy samples apply to persons experiencing severe mental illness.

Surprisingly, the mean Absorption and Psychoticism levels for undergraduates in Study 1 were comparable to the scores of participants with schizophrenia and bipolar disorders in Study 2. High scores in the general population has been noted in the development of other scales for clinical populations. Peters and colleagues found that conviction, distress, and preoccupation rather than content of delusions differentiated healthy adults from those with functionally impairing mental health problems (Peters, Joseph, Day, & Garety, 2004; Peters, Joseph, & Garety, 1999). However, reporting may vary between clinical and non-clinical populations on personality traits as well as state-based clinical features. Frame-of-reference is one possible cause for reporting differences (Bing, Whanger, Davison, & VanHook, 2004). Stigmatized groups like persons with severe mental illness may identify with and rate questionnaires items based on peers who also experience mental illness (Crabtree, Haslam, Postmes, & Haslam, 2010). The two current studies may have inadvertently influenced frame-of-reference since participants in Study 1 consented to research of creativity whereas participants in Study 2 consented to a study of biomarkers of schizophrenia. If traits are to be applied in clinical settings, we must gather reliable population normative scores and understand factors influencing stability and reliability of reporting.

The hypotheses that traits of apophenia would be moderated by intelligence was not supported by either study. IQ and disorganized thinking contribute to individual differences in low and high-level visual tasks (Partos et al., 2016; Tadin, 2015). The inclusion of bipolar disorder and first-degree relatives in the current research was intended to attain a portion of people with elevated apophenia and intact intelligence. Persons with bipolar disorder and their relatives do not have the IQ deficits observed in schizophrenia (Khandaker, Barnett, White, & Jones, 2011; Klimes-Dougan, Jeong, Kennedy, & Allen, 2017; Torres, Boudreau, & Yatham, 2007). Our strategic sampling may have introduced more noise through which to detect a signal; a larger study with more than 200 participants would provide more reliable data. However, we did not observe an interaction in Study 1 either. The interaction may stem from differential relationships to cognitive processes. This argument is not mutually exclusive from the present hypotheses, but suggests the relationship is more complex than a simple trait interaction (e.g., the interaction might only appear in tasks that recruit specific processes). A study that integrates multiple levels of visual processing could isolate the specific relationship between traits and task demands. A broader set of processes outside vision also needs to be considered. For example, attentional discrepancies can reduce response across visual areas (Kanwisher & Wojciulik, 2000).

Other factors could also be investigated as possible moderators. Our findings show that age and visual acuity are important to consider, especially in clinical populations. Age could be tied to chronicity effects. Patients with chronic schizophrenia perform more poorly on visual integration tasks than patients who have experienced a single psychotic episode (Feigenson et al., 2014; Keane et al., 2016). Visual suppression of irrelevant info is also worse with older age, as well as in schizophrenia (Gazzaley et al., 2008). Adding a visual acuity measure to studies of normative populations will show whether physically-based vision differences interact with the predictive power of apophenia traits.

One measurement issue that remains is whether apophenia is related to seeing more beneficial patterns or just seeing *more patterns.* In other words, is the relationship one of quality or of quantity? The current studies took the position that apophenia would be related to quantity, or overall detection rates including false alarms. Frequent false alarms, or Type I errors, are observed in persons with schizophrenia (Brugger & Graves, 1997; Knott et al., 1999) and high positive schizotypy (Fyfe et al., 2008; Partos et al., 2016) across a variety of tasks. Heightened ability to discern a visual target within perceptual noise may be mirrored in falsely perceiving scrambled stimuli as meaningful, perhaps due to reduced surround suppression when target and background elements are similarly oriented (Schallmo et al., 2013; Yoon et al., 2009). Participants believe errors are correct when they rate their confidence (Moritz, Göritz, et al., 2014; Moritz, Ramdani, et al., 2014). Thus, they appear engaged in the task and convinced they are accurately discerning stimuli. The pattern of overconfidence and associated random noise is directly linked to a pharmacological model of schizophrenia and a biological pathway that is disrupted in psychosis. Increased dopamine levels, as induced by dopamine agonist L-dopa, increase false alarm rates and confidence in erroneous responses, whereas decreased dopamine levels reduced false alarm rates and confidence in healthy controls (Andreou, Bozikas, Luedtke, & Moritz, 2015). Dopamine levels shift over the course of psychotic illness and are a theoretical source of visual perceptual differences between first-episode and chronic patients with schizophrenia (Silverstein, 2016). The analysis of d' in Study 2 suggests that apophenia is more closely related to quality, in the form of accuracy measures that account for false alarms. False alarms are an important element of response patterns, but it seems to be the balance between false alarms and hits – the accuracy of responses – that is more related to apophenia.

The current studies focused on trait-based variables and did not consider the clinical state, such as symptom domains and a general psychopathology factor, of participants. Behavioral deficits on visual integration tasks have been linked to positive and negative symptoms, variability in patient insight, and outcome measures (Lysaker et al., 2007; Silverstein & Keane, 2011). Recently, Silverstein & Thompson (2015) theorized more specific clinical relationships: disorganized symptoms are linked to arranging visual information, while select positive symptoms such as hallucinations and delusions decrease the ability to resolve visual features using prior knowledge. The two known longitudinal studies are equivocal. One indicates that amelioration of disorganized symptoms correlates with contour integration performance, while the other finds no relationship between visual integration performance and any symptom factors (Feigenson et al., 2014; Uhlhaas et al., 2005); patient samples are less than 20 in both studies. Traits may also be malleable to changes in clinical state; increases in Openness also follow acute, drug-induced psychotic-like symptoms, connecting the scale to pharmacological models of clinical symptomatology (MacLean, Johnson, & Griffiths, 2011).

Understanding the role personality plays in vision is important to clinical treatment of severe mental illness. Poor functional outcome – a reality for more than half of people affected by schizophrenia – is predicted by perceptual deficits (Hegarty, Baldessarini, Tohen, Waternaux, & Oepen, 1994; Mitelman & Buchsbaum, 2007). Emerging translational visual integration research, links visual tasks to functional outcome and recovery. Visual remediation training improves vision and generalizes to real-world functioning in healthy controls (Campana & Maniglia, 2015; Deveau, Ozer, & Seitz, 2014) and the first threes case studies of a larger randomized control study (Butler, Thompson, Seitz, Deveau, & Silverstein, 2017). Both state- and trait-based measures fit into the translational framework. If personality variables are associated with visual integration in psychosis, they may serve as predictors to treatment response.

Conclusions

The proposed research sought to expand understanding of visual integration through personality traits and neural network timing in healthy controls, persons with schizophrenia spectrum disorders, and relatives. The results of Study 1, in which Openness, Absorption, and Psychoticism positively predicted object detection, motivate future research of personality and perception. Future analyses must address the disconnect between findings in normative and clinical populations. Furthermore, a more complete model of the cognitive processes that support visual integration is needed to understand how neural abnormalities are associated with adaptive and maladaptive perceptual interpretations. In tandem the two studies add to an established area of translational vision research in psychosis by drawing connections to clinical phenomenology observed in psychosis and dimensional models of trait-level individual differences.

Bibliography

Albright, T. D., & Stoner, G. R. (2002). Contextual Influences on Visual Processing. *Annual Review of Neuroscience*, *25*(1), 339–379. https://doi.org/10.1146/annurev.neuro.25.112701.142900

Allen, T. A., & DeYoung, C. G. (2017). Personality neuroscience and the five factor model. In T. A. Widiger (Ed.), *The Oxford Handbook of the Five Factor Model* (pp. 319–352). New York, NY: Oxford University Press. Retrieved from https://books.google.com/books?hl=en&lr=&id=geI-DgAAQBAJ&oi=fnd&pg=PA319&dq=info:EWqY5bXBL2IJ:scholar.google.com&ots=_Q1bJtAlRI&sig=0QxQ-mexgRLsFE4hQ9RcXiEnKvg#v=onepage&q&f=false

Allen, T., & DeYoung, C. (2016). Personality neuroscience and the five factor model. In T. Widiger (Ed.), *Oxford Handbook of the Five Factor Model* (1st ed., p. 319). New York, NY: Oxford University Press.

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders, Text Revision (DSM-IV-TR)* (4th ed.).

Amiaz, R., Vainiger, D., Gershon, A. A., Weiser, M., Lavidor, M., & Javitt, D. C. (2016). Applying Transcranial Magnetic Stimulation (TMS) Over the Dorsal Visual Pathway Induces Schizophrenia-like Disruption of Perceptual Closure. *Brain Topography*, *29*(4), 552–560. https://doi.org/10.1007/s10548-016-0487-1

Amoruso, L., Cardona, J., Melloni, M., Sedeño, L., & Ibanez, A. (2012). Contextual impairments in schizophrenia and the FN400. *Frontiers in Human Neuroscience*, *6*, 191. https://doi.org/10.3389/fnhum.2012.00191

Andreasen, N. C. (1983). *Scale for the Assessment of Negative Symptoms (SANS)*. Iowa City: University of Iowa.

Andreasen, N. C. (1984). *Scale for the Assessment of Positive Symptoms (SAPS)*. Iowa City: University of Iowa.

Andreasen, N. C. (1990). *Schizophrenia: Positive and negative symptoms and syndromes.* Karger.

Andreou, C., Bozikas, V. P., Luedtke, T., & Moritz, S. (2015). Associations between visual perception accuracy and confidence in a dopaminergic manipulation study. *Frontiers in Psychology*, *6*(414), 1–7. https://doi.org/10.3389/fpsyg.2015.00414

Antinori, A., Carter, O. L., & Smillie, L. D. (2017). Seeing it both ways: Openness to experience and binocular rivalry suppression. *Journal of Research in Personality*, *68*, 15–22. https://doi.org/10.1016/J.JRP.2017.03.005

Asai, T., Sugimori, E., Bando, N., & Tanno, Y. (2011). The hierarchic structure in schizotypy and the five-factor model of personality. *Psychiatry Research*, *185*(1–2), 78–83. https://doi.org/10.1016/J.PSYCHRES.2009.07.018

Azadmehr, H., Rupp, A., Andermann, M., Pavicic, D., Herwig, K., Weisbrod, M., … Oelkers-Ax, R. (2013). Object recognition deficit in early- and adult-onset schizophrenia regardless of age at disease onset. *Psychiatry Research: Neuroimaging*, *214*(3), 452–458. https://doi.org/10.1016/j.pscychresns.2013.08.010

Baez, S., Herrera, E., Villarin, L., Theil, D., Gonzalez-Gadea, M. L., Gomez, P., … Ibañez, A. M. (2013). Contextual Social Cognition Impairments in Schizophrenia and Bipolar Disorder. *PLoS ONE*, *8*(3), e57664. https://doi.org/10.1371/journal.pone.0057664

Bar, M., Kassam, K. S., Ghuman, A. S., Boshyan, J., Schmid, A. M., Dale, A. M., … Halgren, E. (2006). Top-down facilitation of visual recognition. *Proceedings of the National Academy of Sciences*, *103*(2), 449–454. https://doi.org/10.1073/pnas.0507062103

Bastos, A. M., Vezoli, J., Bosman, C. A., Schoffelen, J.-M., Oostenveld, R., Dowdall, J. R., … Fries, P. (2015). Visual Areas Exert Feedforward and Feedback Influences through Distinct Frequency Channels. *Neuron*, *85*(2), 390–401. https://doi.org/10.1016/J.NEURON.2014.12.018

Bedwell, J. S., Chan, C. C., Trachik, B. J., & Rassovsky, Y. (2013). Changes in the visual-evoked P1 potential as a function of schizotypy and background color in healthy young adults. *Journal of Psychiatric Research*, *47*(4), 542–547. https://doi.org/10.1016/j.jpsychires.2012.12.012

Bing, M. N., Whanger, J. C., Davison, H. K., & VanHook, J. B. (2004). Incremental Validity of the Frame-of-Reference Effect in Personality Scale Scores: A Replication and Extension. *Journal of Applied Psychology*, *89*(1), 150–157. Retrieved from http://psycnet.apa.org/buy/2004-10572-012

Brooker, B. H., & Cyr, J. J. (1986). Tables for clinicians to use to convert WAIS-R short forms. *Journal of Clinical Psychology*, *42*(6), 982–986. https://doi.org/10.1002/1097-4679(198611)42:6<982::aid-jclp2270420624>3.0.co;2-g

Brugger, P., & Graves, R. E. (1997). Testing vs. believing hypotheses: Magical ideation in the judgement of contingencies. *Cognitive Neuropsychiatry*, *2*(4), 251–272. https://doi.org/http://doi.org/10.1080/135468097396270

Bullier, J. (2001). Integrated model of visual processing. *Brain Research Reviews*, *36*(2–3), 96–107. https://doi.org/10.1016/S0165-0173(01)00085-6

Butler, P. D., Abeles, I. Y., Silverstein, S. M., Dias, E. C., Weiskopf, N. G., Calderone, D. J., & Sehatpour, P. (2013). An event-related potential examination of contour integration deficits in schizophrenia. *Frontiers in Psychology*, *4*, 132. https://doi.org/10.3389/fpsyg.2013.00132

Butler, P. D., Thompson, J. L., Seitz, A. R., Deveau, J., & Silverstein, S. M. (2017). Visual perceptual remediation for individuals with schizophrenia: Rationale, method, and three case studies. *Psychiatric Rehabilitation Journal*, *40*(1), 43–52. https://doi.org/10.1037/prj0000212

Calkins, M. E., Curtis, C. E., Grove, W. M., & Iacono, W. G. (2004). Multiple dimensions of schizotypy in first degree biological relatives of schizophrenia patients. *Schizophrenia Bulletin*, *30*(2), 317–325. https://doi.org/10.1093/oxfordjournals.schbul.a007081

Camisa, K. M., Bockbrader, M. A., Lysaker, P., Rae, L. L., Brenner, C. A., & O'Donnell, B. F. (2005). Personality traits in schizophrenia and related personality disorders. *Psychiatry Research*, *133*(1), 23–33. https://doi.org/10.1016/j.psychres.2004.09.002

Campana, G., & Maniglia, M. (2015). Editorial: Improving visual deficits with perceptual learning. *Frontiers in Psychology*, *6*, 491. https://doi.org/10.3389/fpsyg.2015.00491

Cardin, V., Friston, K. J., & Zeki, S. (2011). Top-down modulations in the visual form pathway revealed with dynamic causal modeling. *Cerebral Cortex*, *21*(3), 550–562. https://doi.org/10.1093/cercor/bhq122

Chmielewski, M., Bagby, R. M., Markon, K., Ring, A. J., & Ryder, A. G. (2014). Openness to Experience, Intellect, Schizotypal Personality Disorder, and Psychoticism: Resolving the controversy. *Journal of Personality Disorders*, *28*(4), 483–499. https://doi.org/10.1521/pedi_2014_28_128

Coleman, M. J., Levy, D. L., Lenzenweger, M. F., & Holzman, P. S. (1996). Thought disorder, perceptual aberrations, and schizotypy. *Journal of Abnormal Psychology*, *105*(3), 469–473.

Conrad, K. (1958). *Die beginnende schizophrenie*. Thième: Stuttgart.

Costa, P., & McCrae, R. (1992). Four ways five factors are basic. *Personality and Individual Differences*, *13*(6), 653–665. https://doi.org/10.1016/0191-8869(92)90237-j

Covington, M. A., He, C., Brown, C., Naçi, L., McClain, J. T., Fjordbak, B. S., … Brown, J. (2005). Schizophrenia and the structure of language: The linguist's view. *Schizophrenia Research*, *77*(1), 85–98. https://doi.org/10.1016/J.SCHRES.2005.01.016

Crabtree, J. W., Haslam, S. A., Postmes, T., & Haslam, C. (2010). Mental Health Support Groups, Stigma, and Self-Esteem: Positive and Negative Implications of Group Identification. *Journal of Social Issues*, *66*(3), 553–569. https://doi.org/10.1111/j.1540-4560.2010.01662.x

Crow, T. J. (1980). Positive and negative schizophrenic symptoms and the role of dopamine. *The British Journal of Psychiatry*, *137*(4), 383–386. https://doi.org/https://www.ncbi.nlm.nih.gov/pubmed/7448479

de Haan, E. H. F., & Cowey, A. (2011). On the usefulness of 'what' and 'where' pathways in vision. *Trends in Cognitive Sciences*, *15*(10), 460–466. https://doi.org/10.1016/J.TICS.2011.08.005

Denève, S., & Jardri, R. (2016). Circular inference: mistaken belief, misplaced trust. *Current Opinion in Behavioral Sciences*, *11*, 40–48. https://doi.org/10.1016/j.cobeha.2016.04.001

Deveau, J., Ozer, D. J., & Seitz, A. R. (2014). Improved vision and on-field performance in baseball through perceptual learning. *Current Biology*, *24*(4), R146–R147. https://doi.org/10.1016/J.CUB.2014.01.004

DeYoung, C. G., Grazioplene, R. G., & Peterson, J. B. (2012). From madness to genius: The Openness/Intellect trait domain as a paradoxical simplex. *Journal of Research in Personality*, *46*(1), 63–78. https://doi.org/10.1016/j.jrp.2011.12.003

DeYoung, C. G., Quilty, L. C., & Peterson, J. B. (2007). Between facets and domains: 10 aspects of the Big Five. *Journal of Personality and Social Psychology*, *93*(5), 880–896. https://doi.org/http://doi.org/10.1037/0022-3514.93.5.880

DiCarlo, J. J., Zoccolan, D., & Rust, N. C. (2012). How does the brain solve visual object recognition? *Neuron*, *73*(3), 415–434. https://doi.org/10.1016/j.neuron.2012.01.010

Dingemans, P. M. A. J., Linszen, D. H., Lenior, M. E., & Smeets, R. M. W. (1995). Component structure of the expanded Brief Psychiatric Rating Scale (BPRS-E). *Psychopharmacology*, *122*(3), 263–267. https://doi.org/10.1007/BF02246547

Docherty, A. R., & Sponheim, S. R. (2008). Anhedonia as a phenotype for the Val158Met COMT polymorphism in relatives of patients with schizophrenia. *Journal of Abnormal Psychology*, *117*(4), 788–798. https://doi.org/10.1037/a0013745

Doniger, G. M., Foxe, J. J., Murray, M. M., Higgins, B. A., & Javitt, D. C. (2002). Impaired visual object recognition and dorsal/ventral stream interaction in schizophrenia. *Archives of General Psychiatry*, *59*(11), 1011–1020. https://doi.org/10.1001/archpsyc.59.11.1011

Doniger, G. M., Foxe, J. J., Murray, M. M., Higgins, B. A., Snodgrass, J. G., Schroeder, C. E., & Javitt, D. C. (2000). Activation timecourse of ventral visual stream object-recognition areas: High density electrical mapping of perceptual closure processes. *Journal of Cognitive Neuroscience*, *12*(4), 615–621. https://doi.org/https://www.ncbi.nlm.nih.gov/pubmed/10936914

Doniger, G. M., Silipo, G., Rabinowicz, E. F., Snodgrass, J. G., & Javitt, D. C. (2001). Impaired Sensory Processing as a Basis for Object-Recognition Deficits in Schizophrenia. *American Journal of Psychiatry*, *158*(11), 1818–1826. https://doi.org/10.1176/appi.ajp.158.11.1818

Ettinger, U., Mohr, C., Gooding, D. C., Cohen, A. S., Rapp, A., Haenschel, C., & Park, S. (2015). Cognition and Brain Function in Schizotypy: A Selective Review. *Schizophrenia Bulletin*, *41*(suppl 2), S417–S426. https://doi.org/10.1093/schbul/sbu190

Farivar, R. (2009). Dorsal–ventral integration in object recognition. *Brain Research Reviews*, *61*(2), 144–153. https://doi.org/10.1016/J.BRAINRESREV.2009.05.006

Feigenson, K. A., Keane, B. P., Roché, M. W., & Silverstein, S. M. (2014). Contour integration impairment in schizophrenia and first episode psychosis: state or trait? *Schizophrenia Research*, *159*(2–3), 515–520. https://doi.org/10.1016/j.schres.2014.09.028

First, M., Spitzer, R., Gibbon, M., & Williams, J. (1997). Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I). In *American Psychiatric Press, Inc.* Washington, D.C.

Foxe, J. J., Murray, M. M., & Javitt, D. C. (2005). Filling-in in schizophrenia: a high-density electrical mapping and source-analysis investigation of illusory contour processing. *Cerebral Cortex*, *15*(12), 1914–1927. https://doi.org/10.1093/cercor/bhi069

Freud, E., Plaut, D. C., & Behrmann, M. (2016). ‘What’ Is Happening in the Dorsal Visual Pathway. *Trends in Cognitive Sciences*, *20*(10), 773–784. https://doi.org/10.1016/J.TICS.2016.08.003

Fusar-Poli, P., Bonoldi, I., Yung, A. R., Borgwardt, S., Kempton, M. J., Valmaggia, L., … McGuire, P. (2012). Predicting psychosis: Meta-analysis of transition outcomes in individuals at high clinical risk. *Archives of General Psychiatry*, *69*(3), 220–229. https://doi.org/10.1001/archgenpsychiatry.2011.1472

Fyfe, S., Williams, C., Mason, O. J., & Pickup, G. J. (2008). Apophenia, theory of mind and schizotypy: perceiving meaning and intentionality in randomness. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *44*(10), 1316–1325. https://doi.org/10.1016/j.cortex.2007.07.009

Gazzaley, A., Clapp, W., Kelley, J., McEvoy, K., Knight, R. T., & D'Esposito, M. (2008). Age-related top-down suppression deficit in the early stages of cortical visual memory processing. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(35), 13122–13126. https://doi.org/10.1073/pnas.0806074105

Gold, J. M., Barch, D. M., Carter, C. S., Dakin, S., Luck, S. J., MacDonald, A. W., … Strauss, M. (2012). Clinical, functional, and intertask correlations of measures developed by the Cognitive Neuroscience Test Reliability and Clinical Applications for Schizophrenia Consortium. *Schizophrenia Bulletin*, *38*(1), 144–152. https://doi.org/10.1093/schbul/sbr142

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, *15*(1), 20–25. https://doi.org/10.1016/0166-2236(92)90344-8

Grill-Spector, K., Kourtzi, Z., & Kanwisher, N. (2001). The lateral occipital complex and its role in object recognition. *Vision Research*, *41*(10), 1409–1422. https://doi.org/10.1016/S0042-6989(01)00073-6

Grove, T. B., Yao, B., Mueller, S. A., McLaughlin, M., Ellingrod, V. L., McInnis, M. G., … Tso, I. F. (2018). A Bayesian model comparison approach to test the specificity of visual integration impairment in schizophrenia or psychosis. *Psychiatry Research*, *265*, 271–278. https://doi.org/10.1016/J.PSYCHRES.2018.04.061

Hanssen, M., Bak, M., Bijl, R., Vollebergh, W., & Os, J. (2005). The incidence and outcome of subclinical psychotic experiences in the general population. *British Journal of Clinical Psychology*, *44*(2), 181–191. https://doi.org/10.1348/014466505X29611

Hegarty, J. D., Baldessarini, R. J., Tohen, M., Waternaux, C., & Oepen, G. (1994). One hundred years of schizophrenia: a meta-analysis of the outcome literature. *American Journal of Psychiatry*, *151*(10), 1409–1416. https://doi.org/10.1176/ajp.151.10.1409

Hurme, M., Koivisto, M., Revonsuo, A., & Railo, H. (2017). Early processing in primary visual cortex is necessary for conscious and unconscious vision while late processing is necessary only for conscious vision in neurologically healthy humans. *NeuroImage*, *150*, 230–238. https://doi.org/10.1016/J.NEUROIMAGE.2017.02.060

Ishizu, T. (2013). Disambiguation of ambiguous figures in the brain. *Frontiers in Human Neuroscience*, *7*, 501. https://doi.org/10.3389/fnhum.2013.00501

Jahshan, C., Wynn, J. K., McCleery, A., Glahn, D. C., Altshuler, L. L., & Green, M. F. (2014). Cross-diagnostic comparison of visual processing in bipolar disorder and schizophrenia. *Journal of Psychiatric Research*, *51*, 42–48. https://doi.org/10.1016/J.JPSYCHIRES.2013.12.014

Jardri, R., & Denève, S. (2013). Circular inferences in schizophrenia. *Brain*, *136*(11), 3227–3241. https://doi.org/http://dx.doi.org/10.1093/brain/awt257

John, O. P., Naumann, L. P., & Soto, C. J. (2008). Paradigm shift to the integrative big five trait taxonomy. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of Personality, Third Edition: Theory and Research* (pp. 114–158).

Joseph, J., Bae, G., & Silverstein, S. M. (2013). Sex, symptom, and premorbid social functioning associated with perceptual organization dysfunction in schizophrenia. *Frontiers in Psychology*, *4*, 547. https://doi.org/10.3389/fpsyg.2013.00547

Kang, S. S., Lano, T. J., Sponheim, S. R., Alschuler, D., Tenke, C., Bruder, G., … Martinerie, J. (2015). Distortions in EEG interregional phase synchrony by spherical spline interpolation: causes and remedies. *Neuropsychiatric Electrophysiology*, *1*(1), 9. https://doi.org/10.1186/s40810-015-0009-5

Kanwisher, N., & Wojciulik, E. (2000). Visual attention: Insights from brain imaging. *Nature Reviews Neuroscience*, *1*(2), 91–100. https://doi.org/10.1038/35039043

Keane, B. P., Joseph, J., & Silverstein, S. M. (2014). Late, not early, stages of Kanizsa shape perception are compromised in schizophrenia. *Neuropsychologia*, *56*, 302–311. https://doi.org/10.1016/j.neuropsychologia.2014.02.001

Keane, B. P., Kastner, S., Paterno, D., & Silverstein, S. M. (2015). Is 20/20 vision good enough? Visual acuity differences within the normal range predict contour element detection and integration. *Psychonomic Bulletin & Review*, *22*(1), 121–127. https://doi.org/10.3758/s13423-014-0647-9

Keane, B. P., Paterno, D., Kastner, S., & Silverstein, S. M. (2016). Visual integration dysfunction in schizophrenia arises by the first psychotic episode and worsens with illness duration. *Journal of Abnormal Psychology*, *125*(4), 543–549. https://doi.org/10.1037/abn0000157

Keane, B. P., Silverstein, S. M., Wang, Y., & Papathomas, T. V. (2013). Reduced depth inversion illusions in schizophrenia are state-specific and occur for multiple object types and viewing conditions. *Journal of Abnormal Psychology*, *122*(2), 506–512. https://doi.org/10.1037/a0032110

Kendler, K., Lieberman, J., & Walsh, D. (1989). The Structured Interview for Schizotypy (SIS): A preliminary report. *Schizophrenia Bulletin*, *15*(4), 559–571. https://doi.org/10.1093/schbul/15.4.559

Kéri, S., Kelemen, O., Benedek, G., & Janka, Z. (2005). Lateral interactions in the visual cortex of patients with schizophrenia and bipolar disorder. *Psychological Medicine*, *35*(7), 1043–1051. https://doi.org/10.1017/S0033291705004381

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Archives of General Psychiatry*, *62*(6), 593–602. https://doi.org/10.1001/archpsyc.62.6.593

Khandaker, G. M., Barnett, J. H., White, I. R., & Jones, P. B. (2011). A quantitative meta-analysis of population-based studies of premorbid intelligence and schizophrenia. *Schizophrenia Research*, *132*(2–3), 220–227. https://doi.org/10.1016/j.schres.2011.06.017

Kim, J. G., Biederman, I., Lescroart, M. D., & Hayworth, K. J. (2009). Adaptation to objects in the lateral occipital complex (LOC): Shape or semantics? *Vision Research*, *49*(18), 2297–2305. https://doi.org/10.1016/j.visres.2009.06.020

King, D. J., Hodgekins, J., Chouinard, P. A., Chouinard, V.-A., & Sperandio, I. (2017). A review of abnormalities in the perception of visual illusions in schizophrenia. *Psychonomic Bulletin & Review*, *24*(3), 734–751. https://doi.org/10.3758/s13423-016-1168-5

Klimes-Dougan, B., Jeong, J., Kennedy, K., & Allen, T. (2017). Intellectual Functioning in Offspring of Parents with Bipolar Disorder: A Review of the Literature. *Brain Sciences*, *7*(11), 143. https://doi.org/10.3390/brainsci7110143

Knezevic, G., Savic, D., Kutlesic, V., & Opacic, G. (2017). Disintegration: A reconceptualization of psychosis proneness as a personality trait separate from the Big Five. *Journal of Research in Personality*, *70*, 187–201. https://doi.org/10.1016/J.JRP.2017.06.001

Knott, V., Mahoney, C., Labelle, A., Ripley, C., Cavazzoni, P., & Jones, B. (1999). Event-related potentials in schizophrenic patients during a degraded stimulus version of the visual continuous performance task. In *Schizophrenia Research*. https://doi.org/10.1016/S0920-9964(98)00122-4

Ko, P. C., Duda, B., Hussey, E. P., Mason, E. J., & Ally, B. A. (2014). The temporal dynamics of visual object priming. *Brain and Cognition*, *91*, 11–20. https://doi.org/10.1016/J.BANDC.2014.07.009

Kopelowicz, A., Ventura, J., Liberman, R. P., & Mintz, J. (2008). Consistency of Brief Psychiatric Rating Scale factor structure across a broad spectrum of schizophrenia patients. *Psychopathology*, *41*(2), 77–84. https://doi.org/10.1159/000111551

Kotov, R., Krueger, R. F., Watson, D., Achenbach, T. M., Althoff, R. R., Bagby, R. M., … Zimmerman, M. (2017). The Hierarchical Taxonomy of Psychopathology (HiTOP): A dimensional alternative to traditional nosologies. *Journal of Abnormal Psychology*, *126*(4), 454–477. https://doi.org/10.1037/abn0000258

Koychev, I., El-Deredy, W., Haenschel, C., & Deakin, J. F. W. (2010). Visual information processing deficits as biomarkers of vulnerability to schizophrenia: An event-related potential study in schizotypy. *Neuropsychologia*, *48*(7), 2205–2214. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2010.04.014

Kravitz, D. J., Saleem, K. S., Baker, C. I., Ungerleider, L. G., & Mishkin, M. (2013). The ventral visual pathway: an expanded neural framework for the processing of object quality. *Trends in Cognitive Sciences*, *17*(1), 26–49. https://doi.org/10.1016/J.TICS.2012.10.011

Krueger, R. F., Derringer, J., Markon, K. E., Watson, D., & Skodol, A. E. (2012). Initial construction of a maladaptive personality trait model and inventory for DSM-5. *Psychological Medicine*, *42*(9), 1879–1890. https://doi.org/10.1017/S0033291711002674

Krug, K., Brunskill, E., Scarna, A., Goodwin, G. M., & Parker, A. J. (2008). Perceptual switch rates with ambiguous structure-from-motion figures in bipolar disorder. *Proceedings. Biological Sciences*, *275*(1645), 1839–1848. https://doi.org/10.1098/rspb.2008.0043

Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology*, *62*(1), 621–647. https://doi.org/10.1146/annurev.psych.093008.131123

Kveraga, K., Ghuman, A. S., & Bar, M. (2007). Top-down predictions in the cognitive brain. *Brain and Cognition*. https://doi.org/10.1016/j.bandc.2007.06.007

Kveraga, K., Ghuman, A. S., Kassam, K. S., Aminoff, E. A., Hämäläinen, M. S., Chaumon, M., & Bar, M. (2011). Early onset of neural synchronization in the contextual associations network. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(8), 3389–3394. https://doi.org/10.1073/pnas.1013760108

Lau, J. K. L., Humphreys, G. W., Douis, H., Balani, A., Bickerton, W., & Rotshtein, P. (2015). The relation of object naming and other visual speech production tasks:A large scale voxel-based morphometric study. *NeuroImage: Clinical*, *7*, 463–475. https://doi.org/10.1016/J.NICL.2015.01.015

Liddle, P. F. (1987). The symptoms of chronic schizophrenia. A re-examination of the positive-negative dichotomy. *The British Journal of Psychiatry*, *151*(2), 145–151. https://doi.org/http://www.ncbi.nlm.nih.gov/pubmed/3690102

Lindenmayer, J.-P., Bernstein-Hyman, R., & Grochowski, S. (1994). A new five factor model of schizophrenia. *Psychiatric Quarterly*, *65*(4), 299–322. https://doi.org/10.1007/BF02354306

Lukoff, D., Liberman, R., & Nuechterlein, K. (1986). Symptom monitoring in the rehabilitation of schizophrenic patients. *Schizophrenia Bulletin*, *12*(4), 578–603. https://doi.org/https://doi.org/10.1093/schbul/12.4.578

Lysaker, P. H., Daroyanni, P., Ringer, J. M., Beattie, N. L., Strasburger, A. M., & Davis, L. W. (2007). Associations of awareness of illness in schizophrenia spectrum disorder with social cognition and cognitive perceptual organization. *The Journal of Nervous and Mental Disease*, *195*(7), 618–621. https://doi.org/10.1097/NMD.0b013e318093f437

MacLean, K. A., Johnson, M. W., & Griffiths, R. R. (2011). Mystical experiences occasioned by the hallucinogen psilocybin lead to increases in the personality domain of openness. *Journal of Psychopharmacology (Oxford, England)*, *25*(11), 1453–1461. https://doi.org/10.1177/0269881111420188

Markov, N. T., Vezoli, J., Chameau, P., Falchier, A., Quilodran, R., Huissoud, C., … Kennedy, H. (2014). Anatomy of hierarchy: Feedforward and feedback pathways in macaque visual cortex. *Journal of Comparative Neurology*, *522*(1), 225–259. https://doi.org/10.1002/cne.23458

Maróthi, R., & Kéri, S. (2018). Enhanced mental imagery and intact perceptual organization in schizotypal personality disorder. *Psychiatry Research*, *259*, 433–438. https://doi.org/10.1016/j.psychres.2017.11.015

Michalareas, G., Vezoli, J., van Pelt, S., Schoffelen, J.-M., Kennedy, H., & Fries, P. (2016). Alpha-Beta and Gamma Rhythms Subserve Feedback and Feedforward Influences among Human Visual Cortical Areas. *Neuron*, *89*(2), 384–397. https://doi.org/10.1016/J.NEURON.2015.12.018

Minzenberg, M. J., Ober, B. A., & Vinogradav, S. (2002). Semantic priming in schizophrenia: A review and synthesis. *Journal of the International Neuropsychological Society*, *8*(5), 699–720. https://doi.org/10.1017/S1355617702801357

Mitelman, S. A., & Buchsbaum, M. S. (2007). Very poor outcome schizophrenia: clinical and neuroimaging aspects. *International Review of Psychiatry*, *19*(4), 345–357. https://doi.org/10.1080/09540260701486563

Mohr, C., & Claridge, G. (2015). Schizotypy--Do Not Worry, It Is Not All Worrisome. *Schizophrenia Bulletin*, *41*(suppl 2), S436–S443. https://doi.org/10.1093/schbul/sbu185

Moritz, S., Göritz, A. S., Van Quaquebeke, N., Andreou, C., Jungclaussen, D., & Peters, M. J. V. (2014). Knowledge corruption for visual perception in individuals high on paranoia. *Psychiatry Research*, *215*(3), 700–705. https://doi.org/10.1016/j.psychres.2013.12.044

Moritz, S., Ramdani, N., Klass, H., Andreou, C., Jungclaussen, D., Eifler, S., … Zink, M. (2014). Overconfidence in incorrect perceptual judgments in patients with schizophrenia. *Schizophrenia Research: Cognition*, *1*(4), 165–170. https://doi.org/10.1016/j.scog.2014.09.003

Mueser, K. T., Curran, P. J., & McHugo, G. J. (1997). Factor structure of the Brief Psychiatric Rating Scale in schizophrenia. *Psychological Assessment*, *9*(3), 196–204. https://doi.org/10.1037/1040-3590.9.3.196

Murray, M. M., Imber, M. L., Javitt, D. C., & Foxe, J. J. (2006). Boundary completion is automatic and dissociable from shape discrimination. *The Journal of Neuroscience*, *26*(46), 12043–12054. https://doi.org/10.1523/JNEUROSCI.3225-06.2006

O'Shea, J., & Walsh, V. (2006). Cognitive neuroscience: Trickle-down theories of vision. *Current Biology*, *16*(6), R206–R209. https://doi.org/10.1016/j.cub.2006.02.030

Olman, C. A., Espensen-Sturges, T., Muscanto, I., Longenecker, J. M., Burton, P. C., Grant, A. N., & Sponheim, S. R. (n.d.). Fragmented Ambiguous Objects: Stimuli with stable low-level features for object recognition tasks.

Panton, K. R., Badcock, D. R., & Badcock, J. C. (2016). A Metaanalysis of Perceptual Organization in Schizophrenia, Schizotypy, and Other High-Risk Groups Based on Variants of the Embedded Figures Task. *Frontiers in Psychology*, *7*, 237. https://doi.org/10.3389/fpsyg.2016.00237

Partos, T. R., Cropper, S. J., & Rawlings, D. (2016). You don't see what I see: Individual differences in the perception of meaning from visual stimuli. *PLoS ONE*, *11*(3), e0150615. https://doi.org/10.1371/journal.pone.0150615

Patrick, C. J., Curtin, J. J., & Tellegen, A. (2002). Development and validation of a brief form of the Multidimensional Personality Questionnaire. *Psychological Assessment*, *14*(2), 150–163.

Peters, E., Joseph, S., Day, S., & Garety, P. (2004). Measuring Delusional Ideation: The 21-Item Peters et al. Delusions Inventory (PDI). *Schizophrenia Bulletin*, *30*(4), 1005–1022. https://doi.org/10.1093/oxfordjournals.schbul.a007116

Peters, E. R., Joseph, S. A., & Garety, P. A. (1999). Measurement of delusional ideation in the normal population: Introducing the PDI (Peters et al. Delusions Inventory). *Schizophrenia Bulletin*, *25*(3), 553–576. https://doi.org/10.1093/oxfordjournals.schbul.a033401

Rahman, R. A., & Sommer, W. (2008). Seeing what we know and understand: How knowledge shapes perception. *Psychonomic Bulletin & Review*, *15*(6), 1055–1063. https://doi.org/10.3758/PBR.15.6.1055

Raine, A. (1991). The SPQ: A scale for the assessment of schizotypal personality based on DSM-III-R criteria. *Schizophrenia Bulletin*, *17*(4), 555–564. https://doi.org/10.1093/schbul/17.4.555

Raine, A., Reynolds, C., Lencz, T., Scerbo, A., Triphon, N., & Kim, D. (1994). Cognitive-perceptual, interpersonal, and disorganized features of schizotypal personality. *Schizophrenia Bulletin*, *20*(1), 191–201. https://doi.org/10.1093/schbul/20.1.191

Richard, F., Bond Jr., C., & Stokes-Zoota, J. (2003). One hundred years of social psychology quantitatively described. *Review of General Psychology*, *7*(4), 331–363. Retrieved from http://psycnet.apa.org/doiLanding?doi=10.1037%2F1089-2680.7.4.331

Rivolta, D., Castellanos, N., Stawowsky, C., Helbling, S., Wibral, M., Grutzner, C., … Uhlhaas, P. J. (2014). Source-reconstruction of event-related fields reveals hyperfunction and hypofunction of cortical circuits in antipsychotic-naive, first-episode schizophrenia patients during Mooney face processing. *Journal of Neuroscience*, *34*(17), 5909–5917. https://doi.org/10.1523/JNEUROSCI.3752-13.2014

Rossi, A., & Daneluzzo, E. (2002). Schizotypal dimensions in normals and schizophrenic patients: A comparison with other clinical samples. *Schizophrenia Research*, *54*(1–2), 67–75. https://doi.org/10.1016/S0920-9964(01)00353-X

Sassi, M., Vancleef, K., Machilsen, B., Panis, S., & Wagemans, J. (2010). Identification of Everyday Objects on the Basis of Gaborized Outline Versions. *I-Perception*, *1*(3), 121–142. https://doi.org/10.1068/i0384

Schallmo, M.-P., Sponheim, S. R., & Olman, C. A. (2013). Abnormal contextual modulation of visual contour detection in patients with schizophrenia. *PloS One*, *8*(6), e68090. https://doi.org/10.1371/journal.pone.0068090

Schneider, U., Borsutzky, M., Seifert, J., Leweke, F. M., Huber, T. J., Rollnik, J. D., & Emrich, H. M. (2002). Reduced binocular depth inversion in schizophrenic patients. *Schizophrenia Research*, *53*(1), 101–108. https://doi.org/10.1016/S0920-9964(00)00172-9

Schürhoff, F., Szöke, A., Méary, A., Bellivier, F., Rouillon, F., Pauls, D., & Leboyer, M. (2003). Familial aggregation of delusional proneness in schizophrenia and bipolar pedigrees. *American Journal of Psychiatry*, *160*(7), 1313–1319. https://doi.org/10.1176/appi.ajp.160.7.1313

Sehatpour, P., Dias, E. C., Butler, P. D., Revheim, N., Guilfoyle, D. N., Foxe, J. J., & Javitt, D. C. (2010). Impaired visual object processing across an occipital-frontal-hippocampal brain network in schizophrenia: an integrated neuroimaging study. *Archives of General Psychiatry*, *67*(8), 772–782. https://doi.org/10.1001/archgenpsychiatry.2010.85

Shaffer, J. J., Johnson, C. P., Fiedorowicz, J. G., Christensen, G. E., Wemmie, J. A., & Magnotta, V. A. (2017). Impaired sensory processing measured by functional MRI in Bipolar disorder manic and depressed mood states. *Brain Imaging and Behavior*, 1–11. https://doi.org/10.1007/s11682-017-9741-8

Shpaner, M., Molholm, S., Forde, E., & Foxe, J. J. (2013). Disambiguating the roles of area V1 and the lateral occipital complex (LOC) in contour integration. *NeuroImage*, *69*, 146–156. https://doi.org/10.1016/j.neuroimage.2012.11.023

Šidák, Z. (1967). Rectangular confidence regions for the means of multivariate normal distributions. *Journal of the American Statistical Association*, *62*(318), 626–633. https://doi.org/10.1080/01621459.1967.10482935

Silberschmidt, A. L., & Sponheim, S. R. (2008). Personality in relation to genetic liability for schizophrenia and bipolar disorder: Differential associations with the COMT Val108/158Met polymorphism. *Schizophrenia Research*, *100*(1–3), 316–324. https://doi.org/10.1016/j.schres.2007.12.467

Silverstein, S. M. (2016). Visual Perception Disturbances in Schizophrenia: A Unified Model (pp. 77–132). Springer, Cham. https://doi.org/10.1007/978-3-319-30596-7_4

Silverstein, S. M., Berten, S., Essex, B., Kovacs, I., Susmaras, T., & Little, D. M. (2009). An fMRI examination of visual integration in schizophrenia. *Journal of Integrative Neuroscience*, *8*(2), 175–202. https://doi.org/10.1142/S0219635209002113

Silverstein, S. M., Harms, M. P., Carter, C. S., Gold, J. M., Keane, B. P., MacDonald, A., … Barch, D. M. (2015). Cortical contributions to impaired contour integration in schizophrenia. *Neuropsychologia*, *75*, 469–480. https://doi.org/10.1016/j.neuropsychologia.2015.07.003

Silverstein, S. M., & Keane, B. P. (2011). Perceptual organization impairment in schizophrenia and associated brain mechanisms: review of research from 2005 to 2010. *Schizophrenia Bulletin*, *37*(4), 690–699. https://doi.org/10.1093/schbul/sbr052

Silverstein, S. M., Keane, B. P., Barch, D. M., Carter, C. S., Gold, J. M., Kovács, I., … Strauss, M. E. (2012). Optimization and validation of a visual integration test for schizophrenia research. *Schizophrenia Bulletin*, *38*(1), 125–134. https://doi.org/10.1093/schbul/sbr141

Silverstein, S. M., & Phillips, W. A. (2003). Cognitive coordination and its neurobiological bases: A new continent to explore. *Behavioral and Brain Sciences*, *26*(1), 110–137.

Snitz, B. E., MacDonald, A. W., & Carter, C. S. (2005). Cognitive deficits in unaffected first-degree relatives of schizophrenia patients: A meta-analytic review of putative endophenotypes. *Schizophrenia Bulletin*, *32*(1), 179–194. https://doi.org/10.1093/schbul/sbi048

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*(1), 34–50. https://doi.org/10.1037/0096-3445.117.1.34

Suzuki, T., Samuel, D. B., Pahlen, S., & Krueger, R. F. (2015). DSM-5 alternative personality disorder model traits as maladaptive extreme variants of the five-factor model: an item-response theory analysis. *Journal of Abnormal Psychology*, *124*(2), 343–354. https://doi.org/10.1037/abn0000035

Swaab, T. Y., Ledoux, K., Camblin, C. C., & Boudewyn, M. (2011). Language-Related ERP Components 4, 397–440.

Tackett, J. L., Silberschmidt, A. L., Krueger, R. F., & Sponheim, S. R. (2009). A dimensional model of personality disorder: Incorporating DSM Cluster A characteristics. *Personality Disorders: Theory, Research, and Treatment*, *S*(1), 27–

34. https://doi.org/10.1037/1949-2715.S.1.27
Tadin, D. (2015). Suppressive mechanisms in visual motion processing: From perception to intelligence. *Vision Research*, *115*(A), 58–70. Retrieved from https://www.sciencedirect.com/science/article/pii/S0042698915002722
Tellegen, A. (1982). *Brief manual for the multidimensional personality questionnaire. Unpublished manuscript, University of Minnesota, ….* University of Minnesota. Retrieved from http://scholar.google.com/scholar?q=%22multidimensional+personality+questionnaire%22&btnG=&hl=en&as_sdt=0%2C24#0
Tellegen, A., & Atkinson, G. (1974a). Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology*, *83*(3), 268–277. https://doi.org/10.1037/h0036681
Tellegen, A., & Atkinson, G. (1974b). Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology*, *83*(3), 268–277.
Tellegen, A., Lykken, D. T., Bouchard, T. J., Wilcox, K. J., Segal, N. L., & Rich, S. (1988). Personality similarity in twins reared apart and together. *Journal of Personality and Social Psychology*, *54*(6), 1031–1039. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/3397862
Teufel, C., Subramaniam, N., Dobler, V., Perez, J., Finnemann, J., Mehta, P. R., … Fletcher, P. C. (2015). Shift toward prior knowledge confers a perceptual advantage in early psychosis and psychosis-prone healthy individuals. *Proceedings of the National Academy of Sciences*, *112*(43), 13401–13406. https://doi.org/10.1073/pnas.1503916112
Torres, I. J., Boudreau, V. G., & Yatham, L. N. (2007). Neuropsychological functioning in euthymic bipolar disorder: a meta-analysis. *Acta Psychiatrica Scandinavica*, *116*(s434), 17–26. https://doi.org/10.1111/j.1600-0447.2007.01055.x
Tsakanikos, E., & Reed, P. (2005). Do positive schizotypal symptoms predict false perceptual experiences in nonclinical populations? *The Journal of Nervous and Mental Disease*, *193*(12), 809–812.
Uhlhaas, P. J., Linden, D. E. J., Singer, W., Haenschel, C., Lindner, M., Maurer, K., & Rodriguez, E. (2006). Dysfunctional long-range coordination of neural activity during Gestalt perception in schizophrenia. *The Journal of Neuroscience*, *26*(31), 8168–8175. https://doi.org/10.1523/JNEUROSCI.2002-06.2006
Uhlhaas, P. J., Phillips, W. A., & Silverstein, S. M. (2005). The course and clinical correlates of dysfunctions in visual perceptual organization in schizophrenia during the remission of psychotic symptoms. *Schizophrenia Research*, *75*(2), 183–192. https://doi.org/10.1016/j.schres.2004.11.005
Uhlhaas, P. J., & Silverstein, S. M. (2005). Perceptual organization in schizophrenia spectrum disorders: Empirical research and theoretical implications. *Psychological Bulletin*, *131*(4), 618–632. https://doi.org/10.1037/0033-2909.131.4.618
Uhlhaas, P. J., Silverstein, S. M., Phillips, W. A., & Lovell, P. G. (2004). Evidence for impaired visual context processing in schizotypy with thought disorder. *Schizophrenia Research*, *68*(2), 249–260. https://doi.org/10.1016/S0920-

9964(03)00184-1
Ungerleider, L. G., & Haxby, J. V. (1994). 'What' and 'where' in the human brain. *Current Opinion in Neurobiology*, *4*(2), 157–165. https://doi.org/10.1016/0959-4388(94)90066-3
Urooj, U., Cornelissen, P. L., Simpson, M. I. G., Wheat, K. L., Woods, W., Barca, L., & Ellis, A. W. (2014). Interactions between visual and semantic processing during object recognition revealed by modulatory effects of age of acquisition. *NeuroImage*, *87*, 252–264. https://doi.org/10.1016/j.neuroimage.2013.10.058
Vancleef, K., Acke, E., Torfs, K., Demeyere, N., Lafosse, C., Humphreys, G., … de-Wit, L. (2015). Reliability and validity of the Leuven Perceptual Organization Screening Test (L-POST). *Journal of Neuropsychology*, *9*(2), 271–298. https://doi.org/10.1111/jnp.12050
Varghese, D., Saha, S., Scott, J. D., Chan, R. C. K., & McGrath, J. J. (2011). The association between family history of mental disorder and delusional-like experiences: A general population study. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, *156*(4), 478–483. https://doi.org/10.1002/ajmg.b.31185
Viertiö, S., Laitinen, A., Perälä, J., Saarni, S. I., Koskinen, S., Lönnqvist, J., & Suvisaari, J. (2007). Visual impairment in persons with psychotic disorder. *Social Psychiatry and Psychiatric Epidemiology*, *42*(11), 902–908. https://doi.org/10.1007/s00127-007-0252-6
Vigário, R. N. (1997). Extraction of ocular artefacts from EEG using independent component analysis. *Electroencephalography and Clinical Neurophysiology*, *103*(3), 395–404. https://doi.org/10.1016/S0013-4694(97)00042-8
Vogel, E. K., & Luck, S. J. (2000). The visual N1 component as an index of a discrimination process. *Psychophysiology*, *37*(02), 190–203. https://doi.org/https://doi.org/10.1111/1469-8986.3720190
Volberg, G., Wutz, A., & Greenlee, M. W. (2013). Top-down control in contour grouping. *PLoS ONE*, *8*(1), e54085. https://doi.org/10.1371/journal.pone.0054085
Voss, J. L., & Federmeier, K. D. (2011). FN400 potentials are functionally identical to N400 potentials and reflect semantic processing during recognition testing. *Psychophysiology*, *48*(4), 532–546. https://doi.org/10.1111/j.1469-8986.2010.01085.x
Wallace, B. (1990). Imagery vividness, hypnotic susceptibility, and the perception of fragmented stimuli. *Journal of Personality and Social Psychology*, *58*(2), 354–359.
Wechsler, D. (1997). *Wechsler Adult Intelligence Scale – Third Edition (WAIS–III)*. (D. Wechsler, Ed.) (3rd ed.). Psychological Corporation.
Wechsler, D. (2008). Wechsler Adult Intelligence Scale–Fourth Edition (WAIS–IV). *San Antonio, TX: NCS Pearson*. Retrieved from http://www.statisticssolutions.com/academic-solutions/resources/directory-of-survey-instruments/wechsler-adult-intelligence-scale-fourth-edition-wais-iv/
Wilson, S., & Sponheim, S. R. (2014). Dimensions underlying psychotic and manic symptomatology: Extending normal-range personality traits to schizophrenia and bipolar spectra. *Comprehensive Psychiatry*, *55*(8), 1809–1819.

https://doi.org/10.1016/j.comppsych.2014.07.008
Yang, E., Tadin, D., Glasser, D. M., Hong, S. W., Blake, R., & Park, S. (2013). Visual context processing in schizophrenia. *Clinical Psychological Science*, *1*(1), 5–15. https://doi.org/10.1177/2167702612464618
Yang, E., Tadin, D., Glasser, D. M., Wook Hong, S., Blake, R., & Park, S. (2013). Visual context processing in bipolar disorder: a comparison with schizophrenia. *Frontiers in Psychology*, *4*, 569. https://doi.org/10.3389/fpsyg.2013.00569
Yaralian, P. (2000). Elevated levels of cognitive-perceptual deficits in individuals with a family history of schizophrenia spectrum disorders. *Schizophrenia Research*, *46*(1), 57–63. https://doi.org/10.1016/S0920-9964(99)00239-X
Yeap, S., Kelly, S. P., Sehatpour, P., Magno, E., Javitt, D. C., Garavan, H., … Foxe, J. J. (2006). Early visual sensory deficits as endophenotypes for schizophrenia: high-density electrical mapping in clinically unaffected first-degree relatives. *Archives of General Psychiatry*, *63*(11), 1180–1188. https://doi.org/10.1001/archpsyc.63.11.1180
Yee, C. M., Javitt, D. C., & Miller, G. A. (2015). Replacing DSM Categorical Analyses With Dimensional Analyses in Psychiatry Research. *JAMA Psychiatry*, *72*(12), 1159. https://doi.org/10.1001/jamapsychiatry.2015.1900
Yoon, J. H., Rokem, A. S., Silver, M. A., Minzenberg, M. J., Ursu, S., Ragland, J. D., & Carter, C. S. (2009). Diminished orientation-specific surround suppression of visual processing in schizophrenia. *Schizophrenia Bulletin*, *35*(6), 1078–1084. https://doi.org/10.1093/schbul/sbp064
Zabelina, D. L., O'Leary, D., Pornpattananangkul, N., Nusslock, R., & Beeman, M. (2015). Creativity and sensory gating indexed by the P50: Selective versus leaky sensory gating in divergent thinkers and creative achievers. *Neuropsychologia*, *69*, 77–84. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2015.01.034

Appendix A. Waveforms and Topography of All ERPs

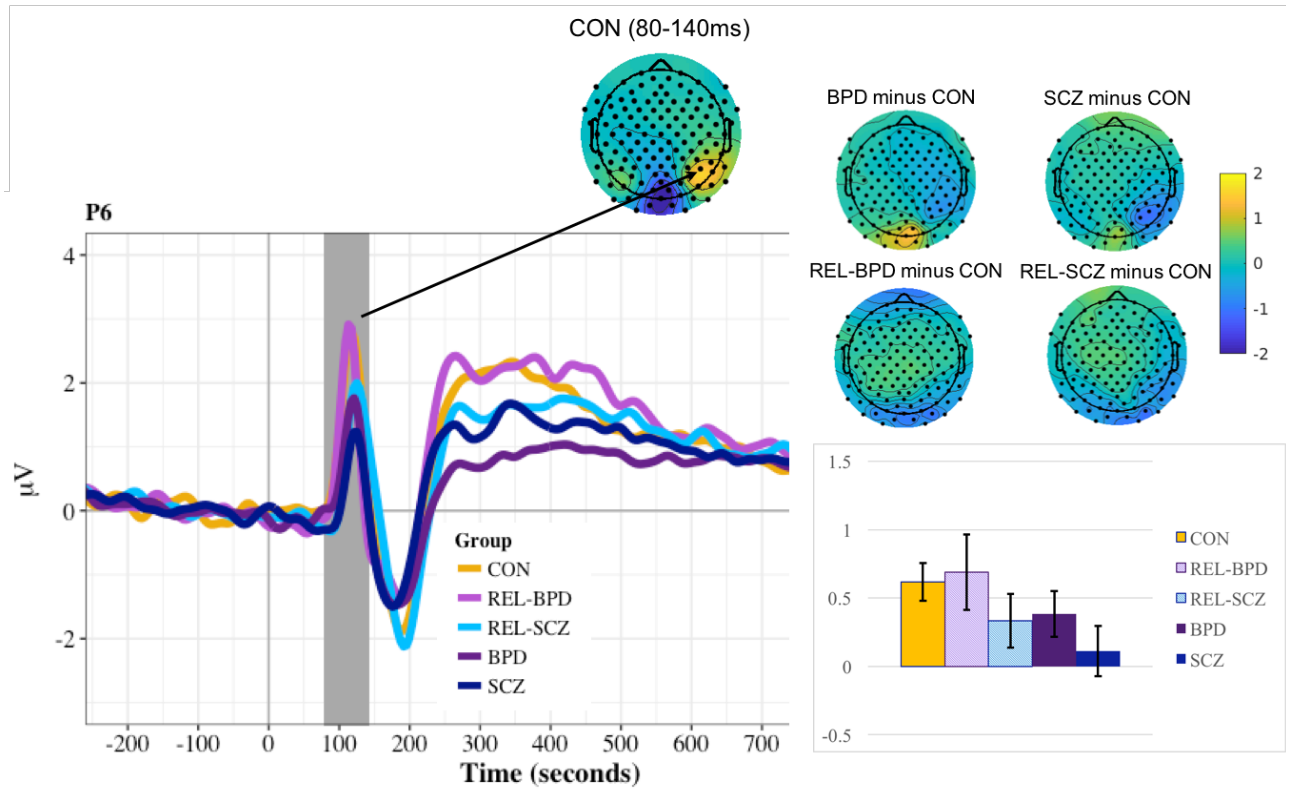

Figure A1. Group Differences in the P1 Component. *The P1 waveform is shown at site P6 with the time window highlighted in gray (left). The mean amplitude of the cluster of electrodes is shown in the bar graph (bottom right). Scalp topography of the controls, and the difference between controls and the other four groups is shown in the scalp maps (top center and right).*

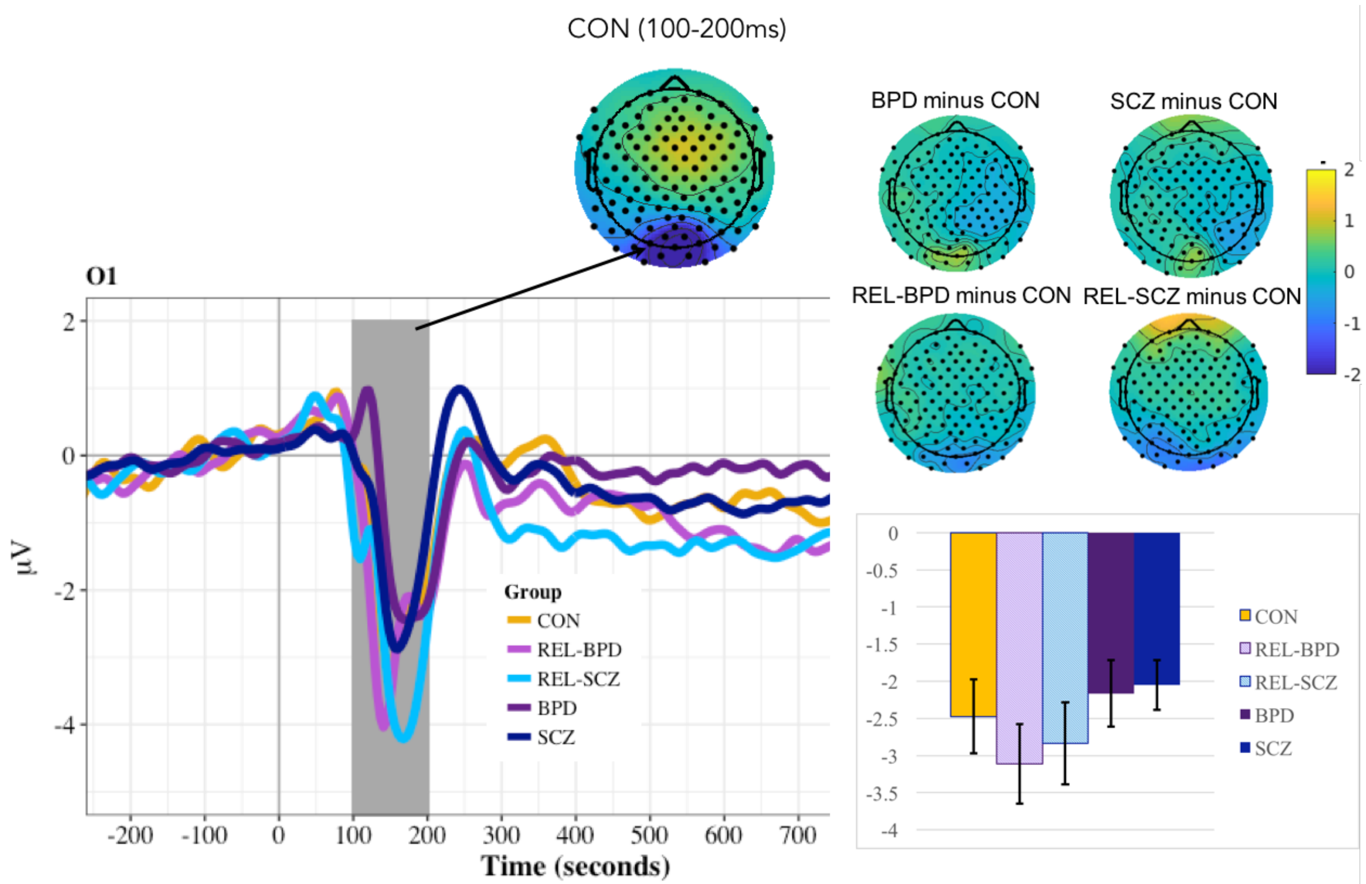

Figure A2. Group Differences in the N1 Component. *The waveform of the N1 component is shown at site O1. Though the waveform shows some separation between the five groups, particularly relatives and patients, there was not a significant difference between groups. The mean amplitude values and standard error of groups is shown in the bar graph (bottom right). Scalp topography for controls (top center) shows the negative deflection at occipital sites; subtractions comparing the relative and patient groups to controls show there is a minimal difference at occipital sites.*

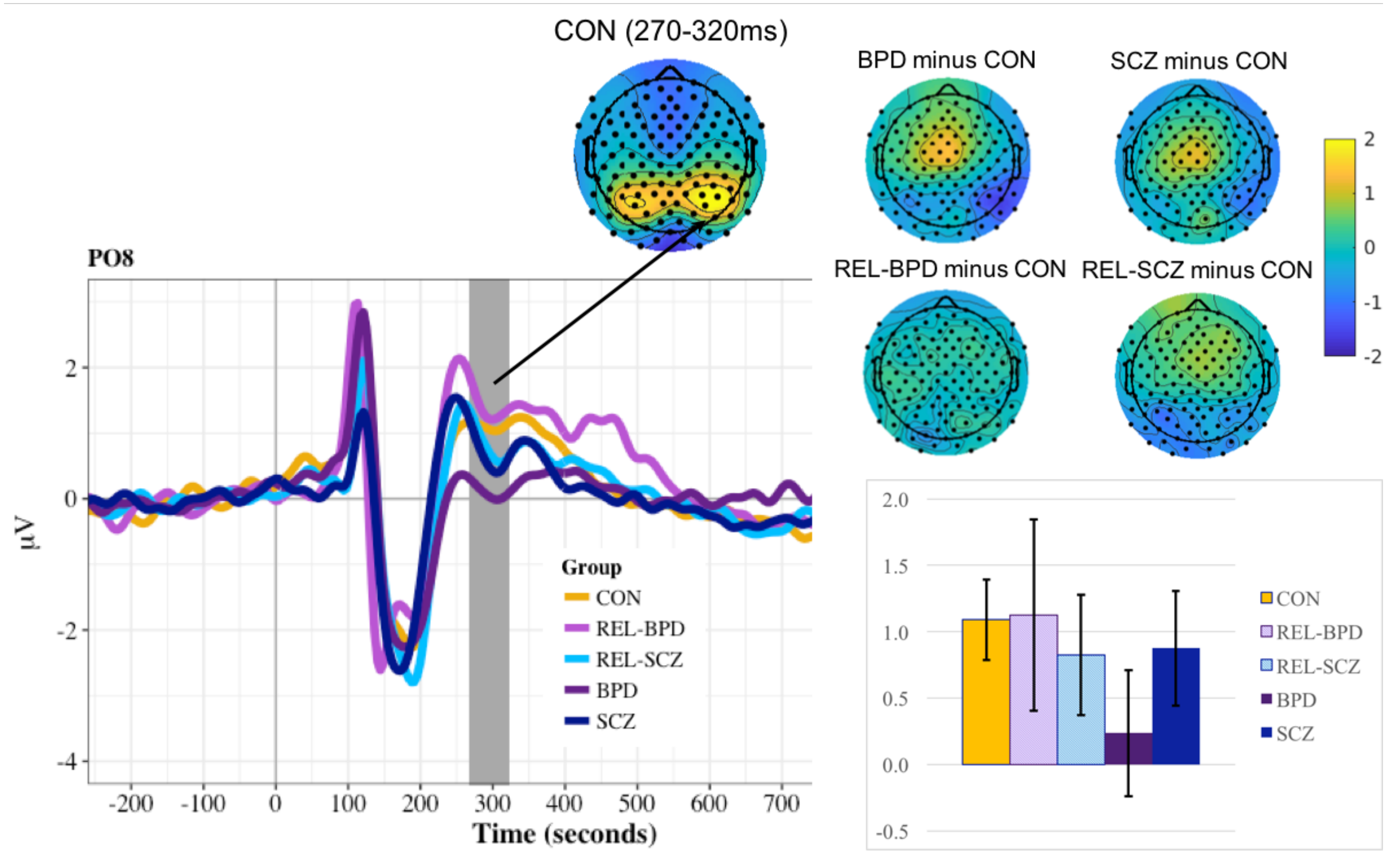

Figure A3. Group Differences in the Negative Closure (N_{CL}) Component*. Groups did not differ in negative closure response. The waveform is depicted at site PO8, one of four electrode sites included in the cluster used to calculate the component value shown in the bar graph (bottom right). Topography maps for the control group, and contrasts between controls and the other four groups, are shown at top right. The N400 response at more central scalp sites can be seen in the topography contrasts of the patient groups.*

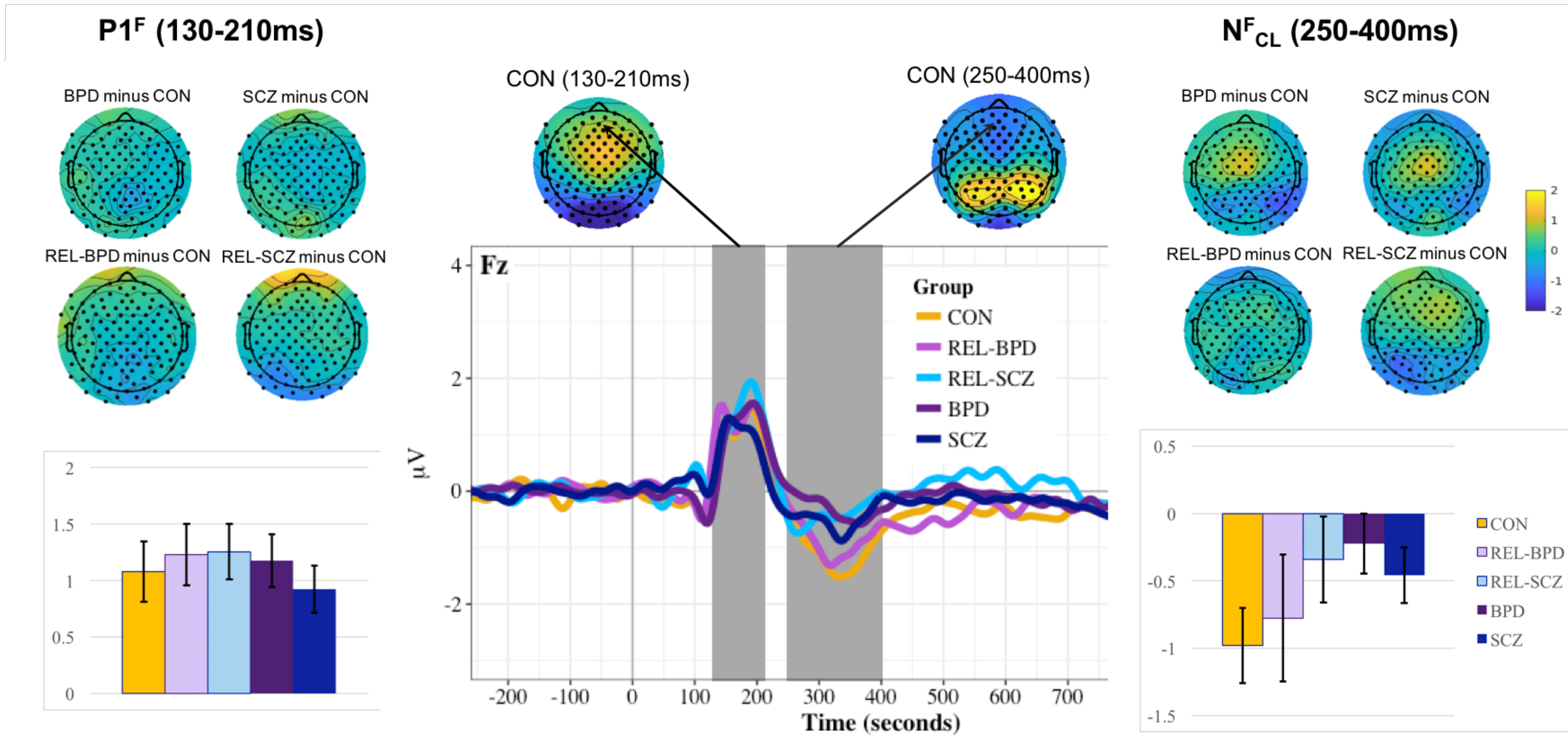

Figure A4. Group Differences in Anterior Components. *Groups did not differ in the early ($P1^F$) or later ($N^F{}_{CL}$) anterior component.* ***Center***: *the waveform at site Fz with ERP time windows highlighted. Above the waveform is scalp topography of healthy controls.* ***Left:*** *$P1^F$ scalp topography contrasting the relative and patient groups with controls are at top. Below, the bar graph shows how much groups overlapped in ERP values; values are averages of the mean amplitude across electrodes in the cluster (F1, Fz, F2); errors bars are standard error.* ***Right:*** *$N^F{}_{CL}$ scalp topography contrasts are shown at top. At bottom, the bar graph shows mean amplitude values used in statistical analyses.*

Appendix B. Image Detectability Effects on ERPs

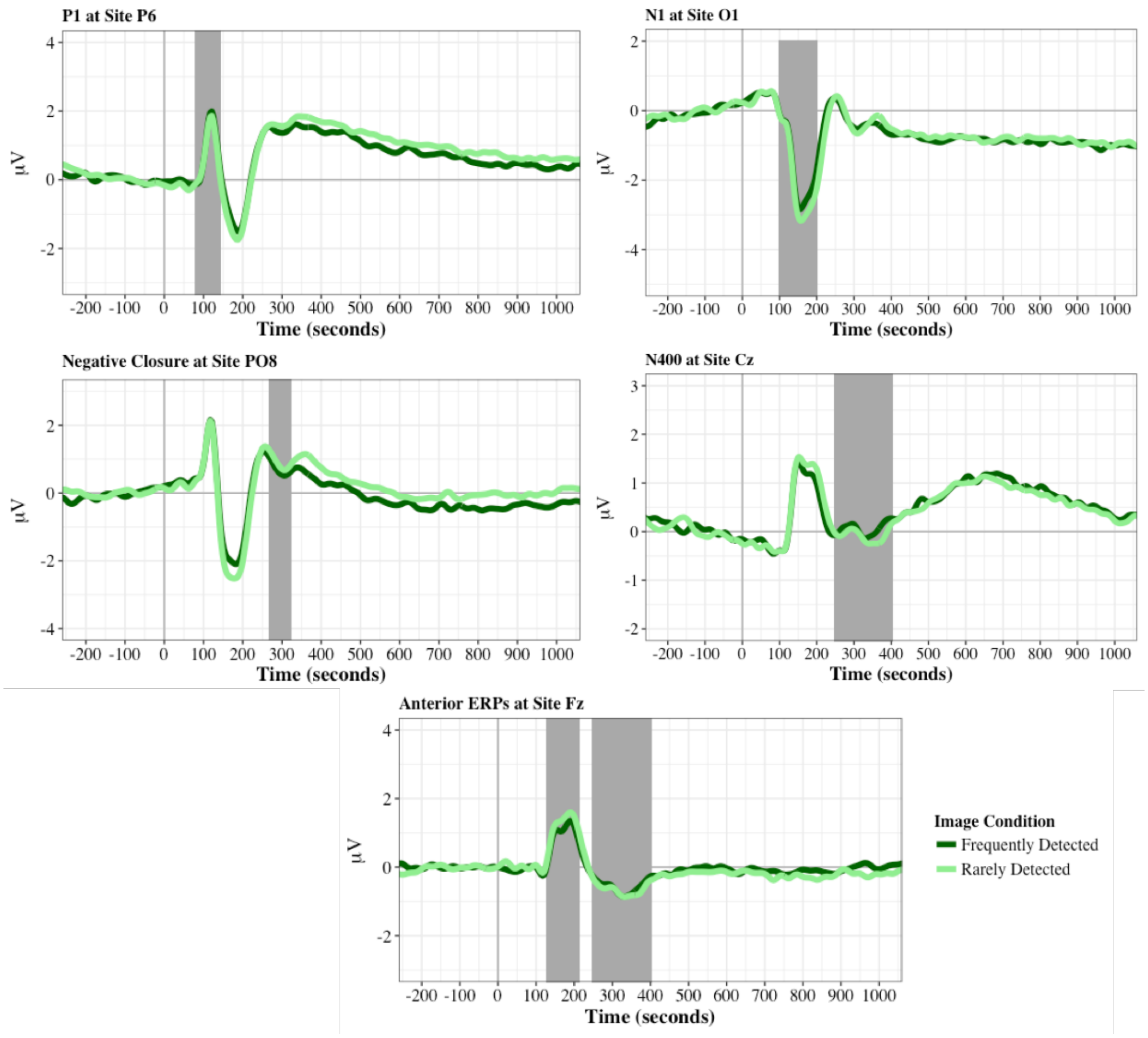

Figure B1. Waveforms for Frequently vs. Infrequently Detected Objects. *Participant ERPs did not differ in response to objects that were easier to detect (>60% mean recognition rate across all participants during the FAOT behavioral task versus those more difficult to detect (<23% mean recognition rate). All five ERP components are depicted above, with the time window of interest highlighted in gray; electrode sites are identical to those illustrated in the corresponding group difference figures. Using the response rates from the behavioral administration of the FAOT version 2 task in Study 2, two stimulus categories were created. The top quartile of images – those to which most participants indicated they saw a known image – forms the Frequently Detected category shown in dark green in the figure above. The bottom quartile of images forms the Infrequently Detected category shown in light green. The same image categorization was used in the calculation of d-prime values detailed in Study 2 methods.*

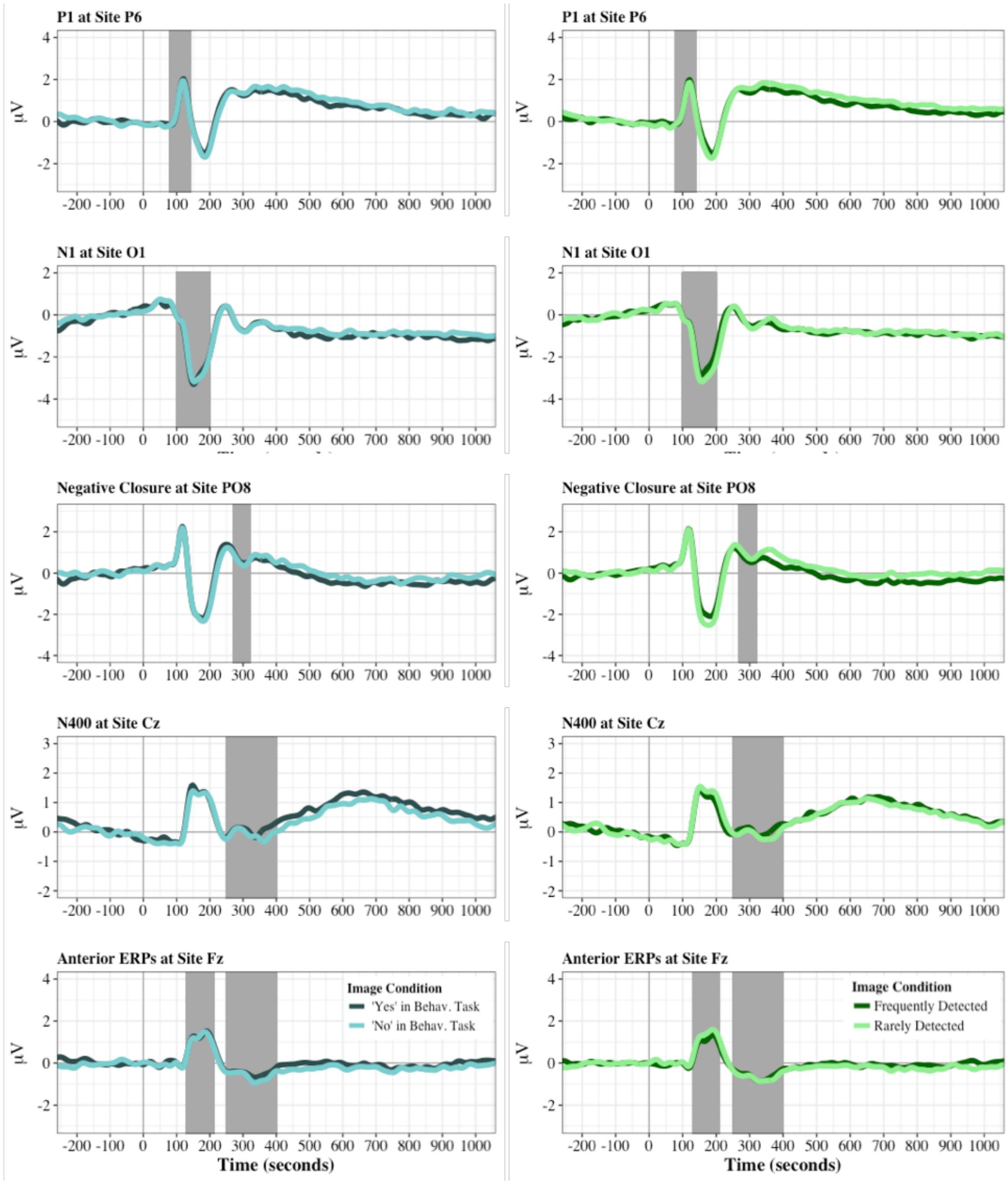

Figure B2. Waveforms of Group and Individual Detection Rates. *A supplementary analysis was carried out to explore whether individual variation in object detection during the behavioral task explained scalp-level deflections during the EEG task better than the image condition based on group rates. The image conditions were comparable in both approaches.* *<u>Left:</u>* *EEG trials were individually keyed for each participant based* *on his/her responses in the behavioral version of the task. For each participant, all images to which he/she responded 'Yes' in the behavioral task were sorted into the 'Yes' category for this analysis. Participants with 20 or more trials per condition were included (N=99; CON=19, REL-BPD=16, REL-SCZ=13, BPD=24, SCZ=27). This was slightly more lenient than the analysis described in the main text, which required at least 25 trials per condition per participant, in order to maximize the sample size.* *Right:* *The waveforms for frequently and infrequently detected image conditions for the same 99 participants included in the individualized analysis and waveforms at left. This is a recreation of Figure B1 using a subset of participants. As described in Figure B1, conditions were calculated using the group mean response rates from the FAOT behavioral task.*

Table B1. Effects of Group and Condition on ERPs of Individualized Response Rates. *The waveforms generated by individual response rates (see left panel or Figure B2) did not differ by condition. A General Linear Model was carried out for all six components with main effects of group and condition, and an interaction between the variables; the inclusion of age, gender, chlorpromazine equivalent, visual acuity, and IQ did not change the significance effects depicted below. ERPs were comparable for images in which participants had previously detected objects during the behavioral task, and images in which they did not see a known object. The group effect for the N400 component was significant, as in the original analyses. Sorting images based on individual participant's responses derived comparable results to analyses based on the mean response rate of the sample.*

	Sum of Squares	Mean Square	*F*	p
Group				
P1	13.24	3.31	2.12	0.080
N1	54.01	13.50	2.29	0.062
Early Anterior ($P1^F$)	8.96	2.24	1.15	0.335
Negative Closure (N_{CL})	30.85	7.71	1.05	0.383
Late Anterior (N^F_{CL})	24.16	6.04	2.42	0.050
N400	26.74	6.68	4.29	0.002*
Condition				
P1	0.09	0.09	0.06	0.807
N1	0.09	0.09	0.02	0.903
Early Anterior ($P1^F$)	0.21	0.21	0.11	0.741
Negative Closure (N_{CL})	0.16	0.16	0.02	0.884
Late Anterior (N^F_{CL})	0.33	0.33	0.13	0.717
N400	0.32	0.32	0.21	0.651
Group x Condition				
P1	2.31	0.58	0.37	0.831
N1	1.04	0.26	0.04	0.996
Early Anterior ($P1^F$)	4.76	1.19	0.61	0.656
Negative Closure (N_{CL})	1.11	0.28	0.04	0.997
Late Anterior (N^F_{CL})	0.53	0.13	0.05	0.995
N400	1.44	0.36	0.23	0.921

Appendix C. Personality Scales

BFAS Openness and Intellect Items

Intellect:
5. Am quick to understand things.
15. Have difficulty understanding abstract ideas.
25. Can handle a lot of information.
35. Like to solve complex problems.
45. Avoid philosophical discussions.
55. Avoid difficult reading material.
65. Have a rich vocabulary.
75. Think quickly.
85. Learn things slowly.
95. Formulate ideas clearly.

Openness:
10. Enjoy the beauty of nature.
20. Believe in the importance of art.
30. Love to reflect on things.
40. Get deeply immersed in music.
50. Do not like poetry.
60. Seldom notice the emotional aspects of paintings and pictures.
70. Need a creative outlet.
80. Seldom get lost in thought.
90. Seldom daydream.
100. See beauty in things that others might not notice.

MPQ Absorption Items

5. Sometimes I feel and experience things as I did when I was a child.
13. I can be greatly moved by eloquent or poetic language.
21. While watching a movie, a T.V. show, or a play, I may become so involved that I forget about myself and my surroundings, and experience the story as if it were real and as if I were taking part in it.
30. If I stare at a picture and then look away from it, I can sometimes see an image of the picture, almost as if I were still looking at it.
37. Sometimes I feel as if my mind could envelop the whole world.
45. I like to watch cloud shapes change in the sky.
53. If I wish I can imagine some things so vividly that it s like watching a good movie or hearing a good story.

60. I think I really know what some people mean when they talk about mystical experiences.
68. I sometimes step outside my usual self and experience a completely different state of being.
73. Textures -- such as wool, sand, wood -- sometimes remind me of colors or music.
81. Sometimes I experience things as if they were doubly real.
90. When I listen to music I can get so caught up in it that I don't notice anything else.
99. If I wish I can imagine that my body is so heavy that I cannot move it.
108. I can often somehow sense the presence of another person before I actually see or hear her/him.
116. The crackle and flames of a wood fire stimulate my imagination.
123. Sometimes I am so immersed in nature or in art that I feel as if my whole state of consciousness has somehow been temporarily changed.
131. Different colors have distinctive and special meanings for me.
141. I can wander off into my thoughts so completely while doing a routine task that I forget what I am doing and a few minutes later find that I have finished it.
149. I can sometimes recall certain past experiences so clearly and vividly that it is like living them again.
156. Things that might seem meaningless to others make sense to me.
165. If I acted in a play I think I would really feel the emotions of the character and become that person for the time being, forgetting both myself and the audience.
173. My thoughts often occur as visual images rather than as words.
182. I am often delighted by small things (like the colors in soap bubbles and the five-pointed star shape that appears when you cut an apple across the core).
189. When listening to organ music or other powerful music, I sometimes feel as if I am being lifted into the air.
197. Sometimes I can change noise into music by the way I listen
208. Some of my most vivid memories are called up by scents and smells.
215. Some music reminds me of pictures or changing patterns of color.
223. I often know what someone is going to say before he or she says it.
231. I often have physical memories; for example, after I've been swimming I may feel as if I'm still in the water.
238. The sound of a voice can be so fascinating to me that I can just go on listening to it.
249. At times I somehow feel the presence of someone who is not physically there.
257. Sometimes thoughts and images come to me without any effort on my part.
265. I find that different smells have different colors.
273. I can be deeply moved by a sunset.

PID-5 Psychoticism Items

5. I often have ideas that are too unusual to explain to anyone.
21. I often say things that others find odd or strange.
24. Other people seem to think my behavior is weird.
25. People have told me that I think about things in a really strange way.

33. My thoughts often go off in odd or unusual directions.
36. I can have trouble telling the difference between dreams and waking life.
37. Sometimes I get this weird feeling that parts of my body feel like they're dead or not really me.
42. People often talk about me doing things I don't remember at all.
44. It's weird, but sometimes ordinary objects seem to be a different shape than usual.
52. My thoughts often don’t make sense to others.
55. People often look at me as if I'd said something really weird.
59. I often see vivid dream-like images when I’m falling asleep or waking up.
70. Others seem to think I'm quite odd or unusual.
71. My thoughts are strange and unpredictable.
77. Sometimes when I look at a familiar object, it's somehow like I'm seeing it for the first time.
83. I often can't control what I think about.
94. I have some unusual abilities, like sometimes knowing exactly what someone is thinking.
99. I sometimes have heard things that others couldn’t hear.
106. I often have unusual experiences, such as sensing the presence of someone who isn't actually there.
139. I have seen things that weren’t really there.
143. I believe that some people can move things with their minds.
150. Sometimes I can influence other people just by sending my thoughts to them.
152. I think about things in odd ways that don't make sense to most people.
154. Sometimes I feel "controlled" by thoughts that belong to someone else.
172. I've been told more than once that I have a number of odd quirks or habits.
185. I have several habits that others find eccentric or strange.
192. Sometimes I think someone else is removing thoughts from my head.
193. I have periods in which I feel disconnected from the world or from myself.
194. I often see unusual connections between things that most people miss.
205. I often have thoughts that make sense to me but that other people say are strange.
209. I've had some really weird experiences that are very difficult to explain.
213. I often "zone out" and then suddenly come to and realize that a lot of time has passed.
217. Things around me often feel unreal, or more real than usual.